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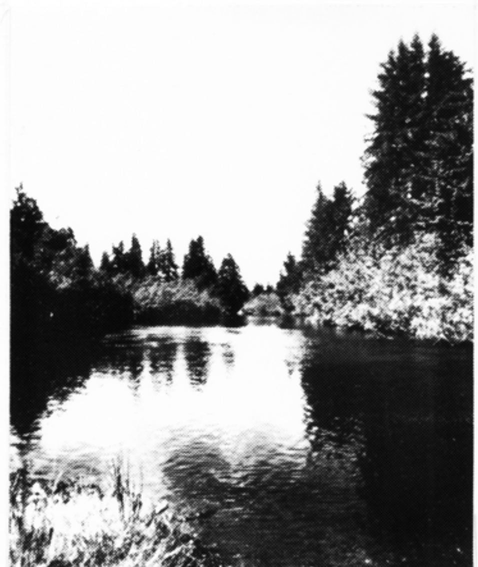

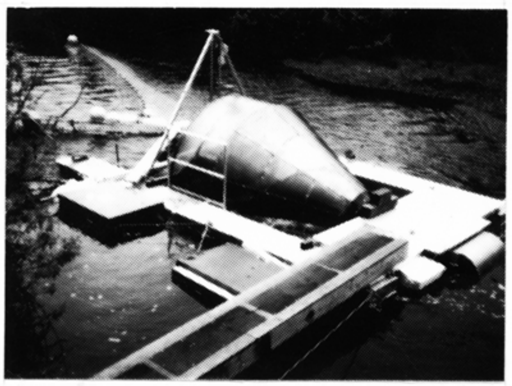

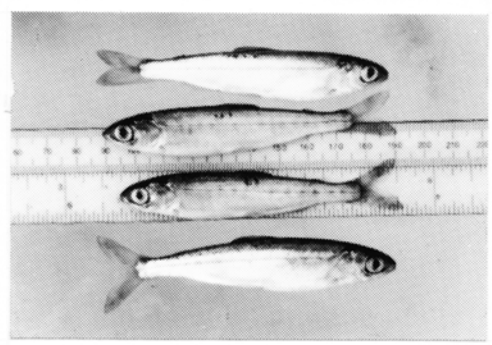

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U.S. DEPARTMENT OF COMMERCE

POTENTIAL EFFECTS OF FLOODING FROM RUSSELL FIORD ON SALMONIDS AND HABITAT IN THE SITUK RIVER, ALASKA

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PREFACE

This report is the culmination of 4 years of study on anadromous fish (principally the salmonids) and habitat of the Situk River, neighboring watersheds, and Russell Fiord, Alaska. The research from 1988 to 1990 was organized and funded through Memorandum of Understanding 88023 between the National Marine Fisheries Service Auke Bay Laboratory, the Alaska Department of Fish and Game, and the U.S. Forest Service to predict the effects of flooding on fish and habitat from overflow of Russell Fiord into the Situk River. This report satisfies the memorandum of understanding requirement of a written report. Results of related research in 1987 by the Auke Bay Laboratory and the U.S. Forest Service are included. This is an informal report; however, portions have been published and are cited as such.

The first major section of this report following the Executive Summary provides background information on the study area. It presents a history and description of the Hubbard Glacier, Russell Fiord, and the Situk River watershed; describes probable physical changes after the flooding, the status of fish stocks and fisheries, and the life histories of anadromous fish species that will be impacted by flooding; and presents a general evaluation of Situk River productivity. The Assessment of Fish and Habitat section presents 10 studies: 9 concerning the Situk River and adjacent watersheds, and 1 pertaining to Russell Fiord. Based on conclusions from the studies and available information, the final two major sections discuss the potential effects of flooding on fish and habitat, and identify possible restoration strategies and research needs.

EXECUTIVE SUMMARY

PURPOSE OF STUDY

This document presents the results of 3 years (1988-90) of cooperative research by the National Marine Fisheries Service (NMFS) Auke Bay Laboratory, Alaska Department of Fish and Game (ADF&G), and United States Forest Service (USFS) on the potential effects of flooding on fish and habitat from overflow of Russell Fiord into the Situk River and neighboring watersheds near Yakutat, Alaska. The study was organized and funded through Memorandum of Understanding (MOU) 88023 between NMFS, USFS, and ADF&G. Research by NMFS and USFS in 1987 is also presented.

The Hubbard Glacier is expected to advance and permanently dam Russell Fiord by the year 2000; the newly formed "Russell Lake" would fill in 7-14 months and then overflow into the Situk River. Flooding would significantly alter Russell Fiord, the Situk and adjacent rivers, and the Situk estuary. The Situk River would change from a clear, stable, primarily groundwater-fed river to a large, unstable glacial river. Average flow would increase by a factor of 37. The river would become cooler and turbid from glacial runoff. The estuary would probably become larger, more turbid, and less saline. Newly formed "Russell Lake" would be about 200 km^2 in size and would have a surface lens of fresh water. Rising water would inundate lower sections of over 100 fiord streams.

Flooding could seriously jeopardize important fisheries in the Yakutat area. Annual returns of the five Pacific salmon species and steelhead to the Situk River are about 450,000 fish of which about one-third are harvested in commercial, subsistence, and sport fisheries. Commercial and recreational fisheries combined are worth approximately $3 million annually to the Yakutat economy.

Research focused on the probable effects of flooding on the life history, habitat, and abundance of adult and juvenile anadromous salmonids. Objectives were to 1) determine the location and use of spawning and rearing habitat; 2) determine characteristics and habitat requirements of stocks with uncommon life histories; 3) predict effects of flooding on habitat and fish production; and 4) suggest strategies to restore fish and habitat that could be impacted by flooding.

ASSESSMENT OF FISH AND HABITAT

Distribution and habitat use of adult sockeye, chinook, and pink salmon in the Situk River were studied in 1988 to determine residence time and number of adults that spawn in the (predicted) flood zone. Similar data were obtained for other species from reports and consultation with biologists. Sockeye and chinook were tagged in the lower Situk River and tracked to spawning areas. Median residence time in the flood zone was 17 days for sockeye and 30 days for chinook. The maximum percentage of adults in the flood zone at any given time differed among species, ranging from less than 10% for fall steelhead trout to nearly 90% for chinook. About one-third of all salmonids spawn within the flood zone: 5% chinook, 5% sockeye, 25% coho, 40% pink, 25% spring steelhead, 0% fall steelhead, and 90% Dolly Varden. All adults use similar migration habitat but different spawning habitat.

Distribution and abundance of juvenile salmonids in summer were estimated in the Situk and Lost Rivers to determine the number of juveniles that rear in the flood zone. Fish density and habitat characteristics were measured in 42 stream reaches in the summers of 1987-89; lakes were not sampled. Fish densities were extrapolated, using the USFS Channel Type Classification System, to the entire Situk and Lost River drainages. About 70% of the total juvenile salmonids in the Situk and Lost Rivers (excluding lakes) reared in the flood zone in summer: over 90% of sockeye, chinook, and Dolly Varden; 70% of coho, and 45% of steelhead. Coho were the most abundant and were present in all study reaches, whereas chinook occurred almost exclusively in the main-stem Situk River. Sockeye were the least abundant and were primarily in Old Situk River. Steelhead occurred in 75% of the study reaches; 40% reared in the West Fork Situk River. Dolly Varden were the second most abundant salmonid—90% reared in Old Situk River.

To determine seasonal use of the main-stem Situk River by juvenile salmonids, fish density and habitat were sampled at four sites in the main stem about every 2 weeks from May to September and in November 1989. Coho, steelhead, and Dolly Varden were common in the main stem from May through November, and sockeye were present from May to late July. In late November, coho and steelhead fry (age < 1) were still common, but parr (age ≥ 1) were virtually absent, except for Dolly Varden. Fry often used channel edges with little cover, but parr primarily used willow edges and pools with abundant cover. Fish densities were higher in the upper main stem than in the lower main stem, probably because of warmer water and more abundant food near the Situk Lake outlet. Thus, the main-stem Situk River is an important summer rearing area for salmonids. The lower river also is an important staging area for fish acclimating to seawater while migrating to sea.

Juvenile chinook and sockeye in the Situk River were studied to document their uncommon "ocean-type" life history. Most chinook and about 5% of juvenile sockeye in the Situk River (including lakes) are ocean type—migrate to sea their first year without wintering in fresh water. Juvenile chinook were sampled at 55 sites in the Situk River and adjacent watersheds from 1987 to 1989. Chinook primarily occupied main-stem habitats (channel edges in spring, pools and willow edges in summer). Chinook migrated downstream in two phases: a spring dispersal of emergent fry, and a summer migration of presmolts. Chinook marked in the upper river in late June and July were recaptured 20 km downstream in the lower river in late July. Marked chinook remained in the lower river for up to 34 days. Mean fork length of chinook in the lower river increased from 40 mm in May to 80 mm in early August. By late August, chinook had emigrated from the lower river, presumably to sea, at a size of about 80 mm. Fish this size had the physical appearance of smolts and, based on seawater-challenge tests, could tolerate seawater.

To determine the life history of ocean-type sockeye, several sites in the upper and lower main-stem Situk and Old Situk Rivers, and in the Situk estuary were sampled in 1987-88. Two separate migrations of sockeye fry were apparent: an early migration of newly-emerged fry into the estuary in March and April and a later migration of larger sockeye from the lower river in May and June. Neither group remained in the estuary or lower river for long; most early migrants disappeared from their primary habitat (tidal sloughs) by mid-May, and most later migrants spent less than 3 weeks in the lower river and estuary. Size was a determining factor in seaward migration. Fry left rearing areas throughout the river and estuary and moved seaward as their size approached 50 mm, the threshold size determined by seawater-challenge tests for 100% survival.

To enumerate migrant juvenile salmonids and evaluate winter habitat, a weir was constructed in 1989 on Old Situk River near its confluence with the Situk River. An estimated 26,200 coho, 7,000 sockeye, 500 steelhead, and 5 chinook smolts migrated from Old Situk River. An estimated 93,000 age-1 coho parr emigrated from Old Situk River and probably reared in the main-stem Situk River until smoltification. An estimated yield of 45 salmonids/100 m^2 (parr and smolts) demonstrates that Old Situk River is important winter habitat.

To determine the yield of salmonid parr and smolts from inside and outside the flood zone and location of winter habitat, rotary-screw traps were fished in the upper and lower main-stem Situk River in 1990. Total smolt yield from the Situk River watershed was 893,000 sockeye (including 128,000 ocean type); 168,000 coho; 67,000 chinook; and 26,000 steelhead. About 30% of the smolts migrated from the flood zone. The percentage of smolts originating from the flood zone differed among species and stocks, ranging from 100% for ocean-type sockeye to 0% for steelhead. Natural smolt mortality during downstream migration through the main stem was estimated to be about 25% and was attributed to predation.

To assess importance of the Situk estuary for juveniles, the Situk Estuary was sampled in spring and summer of 1987-88. The estuary serves as a productive spring and summer rearing area for salmon fry, particularly ocean-type sockeye, and is a migration corridor for anadromous fish entering or leaving fresh water. The estuary also provides habitat for at least 11 species of marine fish and numerous invertebrates, including Dungeness crab.

Summer distribution of juvenile salmonids in streams entering Russell and Nunatak Fiords was determined to evaluate potential loss from flooding. Rearing salmonids occurred in only 30 of 102 streams sampled. Juvenile Dolly Varden were in 30 streams; coho were in only 9 streams. Streams without juvenile salmonids were usually short and steep and had poor spawning and rearing habitat. Thus, Russell and Nunatak Fiord streams are generally unproductive and do not contribute substantially to fish production in the Yakutat area.

Five baseline sites were established to characterize juvenile salmonid abundance and habitat so that changes after flooding could be evaluated. Sites (three inside and two outside the flood zone of the Situk and Lost Rivers) were sampled in summer and fall from 1987 to 1990. Variables measured include fish density, amount of large woody debris, pool-rifle ratio, stream size, and water temperature. Coho were at all sites and were the most abundant salmonid; sockeye were least abundant and were at only two sites. Densities were generally lower in fall than in summer and varied annually in both summer and fall.

PREDICTED EFFECTS OF FLOODING

After Hubbard Glacier impounds Russell Fiord, most spawning and rearing habitat in Russell Lake streams and about 70% of the Situk River would be flooded. Overflow from Russell Lake would severely impact Old Situk River and the main-stem Situk River downstream from its confluence. Old-growth forest in the floodplain would be destroyed, and log jams would intensify flooding. Stream gravel would be scoured, shifted, and often filled with fine sediment. The greatest impact of flooding on fish and habitat would be from initial flooding or from successive flooding events caused by the formation and destruction of glacial dams. Habitats would be unstable for several years as the river channel adjusts to increased flow and changes in sediment and debris.

In the Situk River, flooding would probably affect juvenile salmonids more than adults; impacts would be greatest in summer because of the abundance of juveniles in the flood zone. However, some juveniles are in the flood zone all year and would be affected anytime flooding occurred. Most affected would be coho, ocean-type sockeye, chinook, and Dolly Varden. Old Situk River was identified as important juvenile winter habitat and would be severely impacted by flooding.

The uncommon ocean-type life histories of sockeye and chinook salmon in the Situk River may be jeopardized by flooding because of changes in their specific requirements. In Alaska, most sockeye and chinook rear at least 1 year in fresh water. Cooler water after flooding could reduce growth and increase freshwater rearing time of ocean-type fish from 4-6 months to 1 or more years.

The severity of effects of flooding on adult salmonids in the Situk River would depend on timing and duration of floods; however, all species will be affected because they all migrate through the flood corridor. Most species primarily spawn upstream of the flood zone and their spawning habitat would not be directly affected; however, 40% of pink salmon spawn inside the flood zone. Displaced pink salmon may compete with other species for spawning habitat outside the flood zone. Ocean-type sockeye also would be severely impacted because nearly all spawn in the Old Situk River, a major corridor for flood waters.

After the Situk River stabilizes, abundance of some species could increase to higher than pre-flood levels because of the formation of new habitats (e.g. secondary floodplain channels, sloughs). For instance, juvenile chinook and sockeye rear successfully in cooler glacial rivers and may benefit from the increased rearing area. If the amount of groundwater increases, there could be benefits to all fish, particularly ocean-type sockeye.

Salmonids in Russell Fiord streams would be severely affected if the Hubbard Glacier dams Russell Fiord. Most rearing and spawning habitat in fiord streams would be flooded, but the new lake could provide extensive rearing habitat. Although access via Yakutat Bay would be eliminated, entry would become available via the Situk River.

RESTORATION STRATEGIES

Restoration efforts to offset the loss of fish and habitat in the Situk River should concentrate on enhancing the recovery of fish stocks or habitats that may recover too slowly or not at all. Appropriate restoration strategies could be implemented after Hubbard Glacier dams Russell Fiord because Russell Lake would take up to 14 months to fill. Costly restoration efforts however, should be limited until after the initial years of flooding to evaluate the response of fish populations and habitat.

Restoration efforts should concentrate on species or stocks considered at high risk (i.e. depressed abundance, high fisheries value, or uncommon life history). Steelhead in the Situk River were considered at the highest risk and have the greatest need for restoration because of their currently depressed population. Steelhead should be managed now to increase their numbers to the historic average to help them withstand the impacts of flooding: a stream management plan should be implemented to prevent further damage to fish habitat; woody debris cutting or log jam removal should be prohibited; and the number of boats and size of outboard motors limited on the Situk River. Restoration for chinook, ocean-type sockeye, and coho should consist of developing new rearing and spawning habitat. Management of the pink escapement may alleviate potential problems caused by an increase in the number of fish spawning outside the flood zone.

Possible restoration projects include construction of ground-water fed spawning channels and rearing ponds, construction of egg-incubation facilities, enhancement of Russell Lake, and changes in fisheries management. Potential restoration sites include groundwater sources near Greens Pond, Milk Creek, Ophir Creek, Cannon Beach Creek, and the Yakutat airport. Diversion of floodwaters and clearing of trees from the floodplain should not be done because of potentially severe damage to fish habitat.

RESEARCH NEEDS

Before flooding, pilot studies should be done to evaluate the effectiveness of the identified restoration strategies. The carrying capacity of the Tawah Creek drainage should be determined before restoration projects are initiated there. Further evaluation of lakes in the Situk and Lost River drainages would help determine their carrying capacities and whether lake enhancement would be warranted. Groundwater sources should be evaluated to determine areas in the Situk River watershed where flow is sufficient to provide year-round water for enhancement or restoration projects. Although restoration in Russell Lake will be difficult because of its wilderness classification, the feasibility of rearing sockeye there should be studied after flooding. Smolt yield should be determined again to establish a baseline for smolt yield and to quantify smolt predation and identify its source. To better predict the effects of increased adult salmon spawning outside the flood zone, the effects of stock interaction should be studied. The contribution of rearing ponds to smolt production should be evaluated before ponds are enhanced or created. Fish populations and habitat should be monitored after flooding to evaluate restoration effectiveness.

HISTORY AND DESCRIPTION OF STUDY AREA

HUBBARD GLACIER AND SITUK RIVER

The advancing Hubbard Glacier (Fig. H.1) dammed Russell Fiord near Yakutat, Alaska (Fig. H.2) in May 1986 and created the world's largest glacier-formed lake. Rising water in the newly formed "Russell Lake" (Fig. H.3) threatened to overflow and flood the Situk River, one of Alaska's most productive salmon and trout rivers. Before flooding could occur, however, the ice dam burst. Based on tidewater glacier cycles, the ice dam is expected to rebuild within the next decade and may persist for hundreds of years (Trabant et al. 1991). Eventually, overflow from "Russell Lake" will probably flood the Situk River and drastically disrupt fisheries. Historically, the Hubbard and other glaciers that originate in icefields of the St. Elias Mountains have repeatedly advanced and retreated over the past 7,000 years, alternately impounding and releasing an enormous lake in the Russell Fiord basin (Mayo 1988). Prior to 1986, the last damming of Russell Fiord and flooding of the Situk River ended in the mid-1800s (De Laguna et al. 1964).

Flooding would change the present Situk River from a small, clear, groundwater-fed river, to a large, unstable, glacial river. USFS hydrologists expect flood waters to follow the same route of previous floods—down the Old Situk River, into the main-stem Situk River, then into the Pacific Ocean via the Lost River (Fig. H.4). The (predicted) flood zone will encompass nearly 70% of the Lost and Situk Rivers. After flooding, average flow will increase by a factor of 37 and the river will be turbid with fine glacial silt and sediment from erosion (Mayo 1988). The

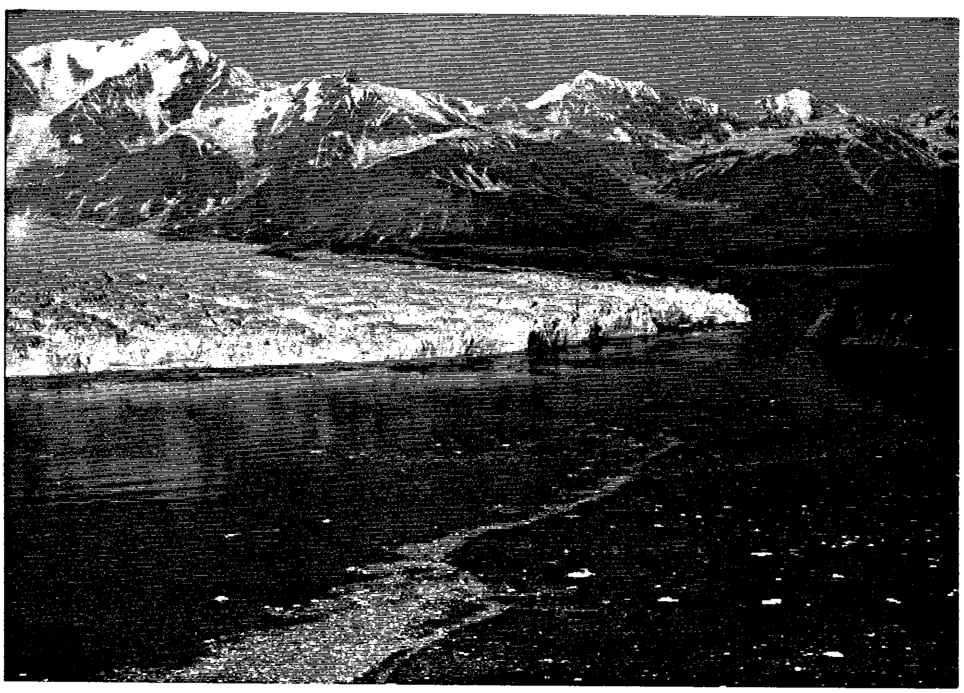

Figure H.1—Hubbard Glacier near Yakutat, Alaska.

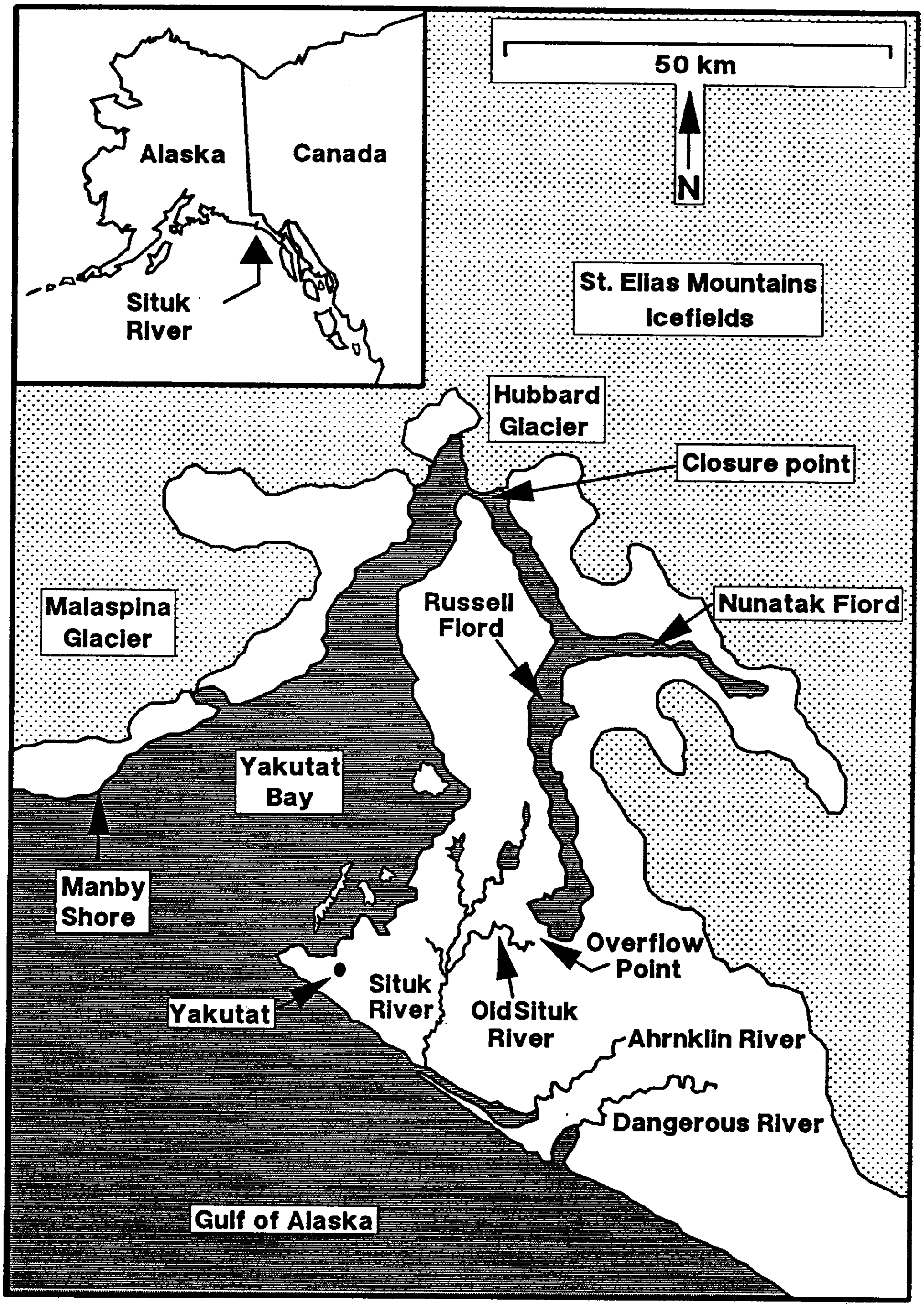

Figure H.2—Location of Hubbard Glacier, Russell Fiord, and Situk River near Yakutat, Alaska, and location of predicted closure of Russell Fiord by Hubbard Glacier and overflow point into the Situk River.

Figure H.3—Russell Lake near Yakutat, Alaska, after Russell Fiord was dammed by Hubbard Glacier in 1986.

first 3-5 years of flooding are expected to be the most destructive. Eventually, the river will stabilize as it regains its former channel.

Flooding could seriously jeopardize important commercial, subsistence, and recreational fisheries in the Yakutat area. Anadromous fish from the Situk River are primarily harvested in terminal gill-net fisheries near the mouth of the river (McPherson et. al 1987; Riffe 1987; Bethers and Ingledue 1989). The Situk River provides approximately 25% of the Yakutat area's commercial gill-net harvest (Pahlke 1989) and also contributes substantially to the off-shore troll fishery. Subsistence harvests of fish and wildlife in Yakutat are some of the highest in Southeast Alaska: an average 168 kg per capita in 1984 (Mills and Firman 1986). Each year, sport anglers from around the world spend a total of 25,000 hours fishing for salmon and steelhead in the Situk River (Bethers and Ingledue 1989). Commercial and recreational fisheries combined are worth approximately $3 million annually to the local economy.

Research began in 1987 to establish a database to help predict the effects of flooding on the production of salmonids and other fish species in the Situk River. From 1987 through 1990, adult and juvenile salmonids were studied in the Situk River and adjacent drainages, the Situk estuary, and Russell Fiord. Objectives were to 1) determine the location and use of spawning and rearing habitat of salmonids; 2) determine characteristics and habitat requirements of stocks with uncommon life histories; 3) predict effects of flooding on fish and habitat; and 4) identify strategies to restore fish and habitat that could be impacted by flooding.

STUDY AREA

Situk River

The Situk River is located 18 km east of Yakutat, Alaska (Fig. H.2), and flows through a glacial outwash plain and uplifted seabed called the Yakutat Forelands. The main stem is 35 km long, originating at Situk Lake (315 ha). The Situk River has an average summer flow of 6 m^3/s (Clark and Paustian 1989). In this report the "lower river" refers to the lowermost 3.5 km of the main-stem Situk River that is influenced by daily tides. At high tide, the lower river deepens, water velocity slows, and salinity increases but remains low (mean bottom salinity less than 5.0‰; Heifetz et al. 1989). The remainder of the main stem upstream of tidal influence is called the "upper river".

The Situk River averages 25 m wide, drains an area about 200 km^2 (USFS 1985), and has two major tributaries (Fig. H.4). Old Situk River is 20 km long and has an average summer flow of 1.5 m^3/s; it originates from a small pond and joins the main stem 17 km upstream of the estuary. The West Fork is 10 km long and has an average summer flow of 1 m^3/s; it flows from Redfield Lake (200 ha) and joins the main stem 21 km upstream of the estuary. Mountain Stream (6 km long) is a tributary to Situk Lake, connecting Situk Lake and Mountain Lake (87 ha). A more detailed description of the Situk River and Russell Fiord watersheds is provided in Riffe (1987).

Discharge in the Situk River is usually greatest in fall after heavy rains (Fig. H.5; Lamke et al. 1990, 1991). From October through December 1989 and 1990, peak monthly discharge ranged from about 10 to 75 m^3/s. From June through August, discharge was more stable, and usually ranged from 5 to 30 m^3/s. A more complete description of Situk River flow is in this section of the report under Reasons for Situk River Productivity.

From 1989 through 1991, water temperature was measured hourly with ENDECO[1] thermographs at seven locations and with a DATAPOD thermograph by the U.S. Geological Survey (USGS) at one location in the Situk River watershed (Fig. H.4). Water temperature varied greatly by location but was similar between years (Fig. H.6). Temperature was usually greatest in July, ranging from 4°C in Situk Meander to 19°C at the Situk Lake outlet. Temperature was usually lowest in January, ranging from 0 to 5°C. The most stable temperature was in Situk Meander, with an annual range from only 3 to 6°C, probably because of groundwater influence.

Neighboring watersheds include Kunayosh Creek (1 km east of Situk River), Seal Creek (8 km east), Ahrnklin River (11 km east), and Lost River (2 km west) (Figs. H.2, H.4). The largest of these watersheds, the Ahrnklin River, is larger than the Situk River.

Situk Estuary

Several rivers, Kunayosh Creek, Seal Creek, and the glacial Ahrnklin River empty into the estuary (Figs. H.2, H.4). The estuary basin is 6 km^2 in area and has mean surface salinity of 17‰, mean bottom salinity of 21‰, and mean depth at low tide of 4.1 m (Heifetz et al. 1989). The estuary also has other important habitat: mudflats, gravel or sand beaches, and numerous small (1-6 m wide) tidal sloughs bordered by *Carex* sp.

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[1]Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

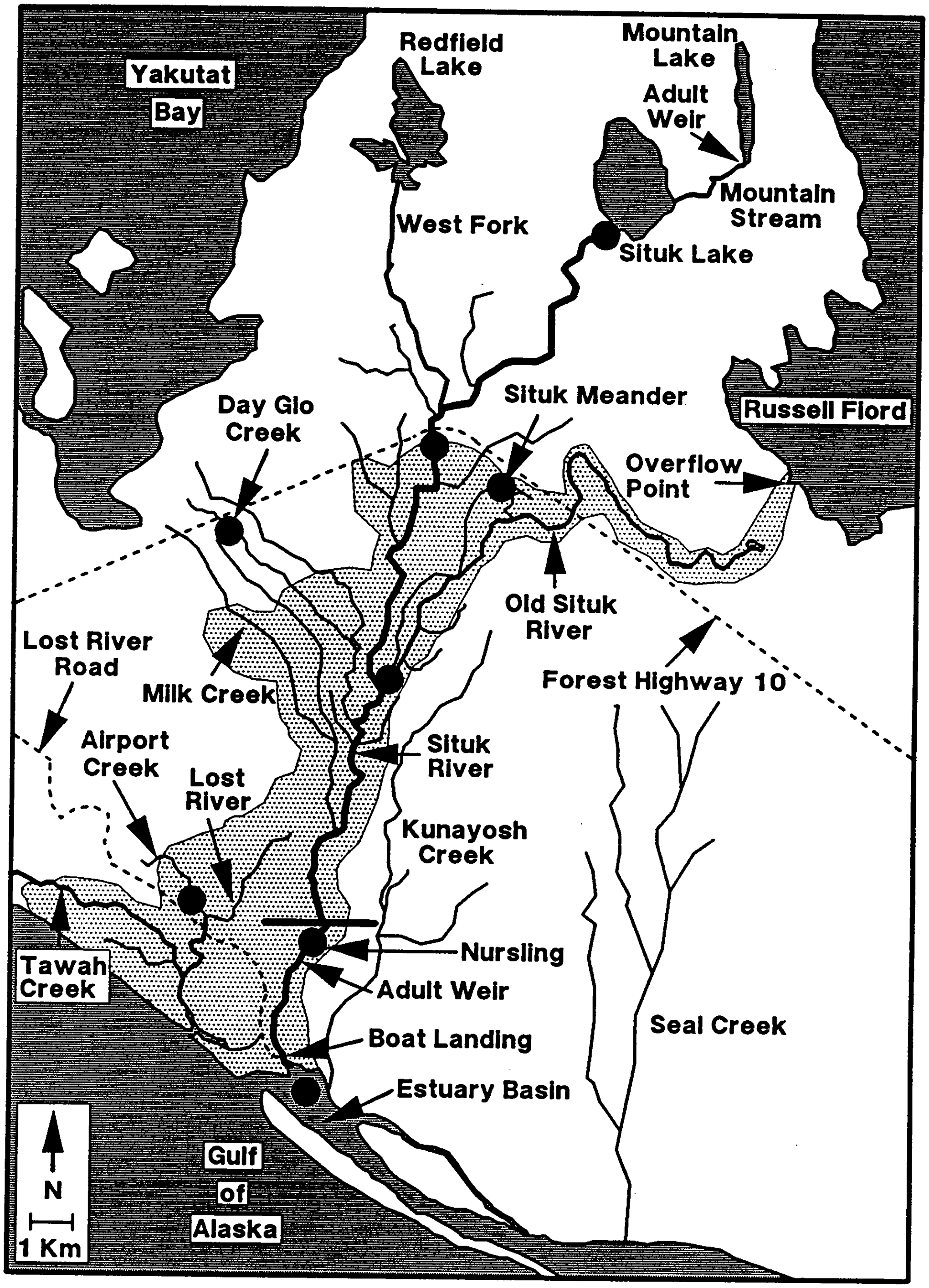

Figure H.4—Map of Situk River and adjacent watersheds. Stippled area is the predicted flood zone. Thermograph sites are designated by circles. Solid line across Situk River represents upper limit of tidal influence and boundary between upper and lower sections of river.

Russell Fiord

Russell Fiord, including Nunatak Fiord, has a watershed area of 1,873 km^2 (Fig. H.2). Russell Fiord is about 60 km long, 3 km wide, and 196 km^2 in area. The landscape is dominated by sparsely vegetated mountains and numerous large glaciers. Elevations range from sea level to over 2,700 m in the St. Elias Mountains. Rainfall and glacial melt account for about 80% of the runoff entering Russell Fiord in more than 100 inlet streams.

Climate

The Yakutat area has a maritime climate; surrounding mountains cool moisture-laden air from the Pacific Ocean, resulting in annual rainfall of 330 cm (Riffe 1987). The heaviest rain falls between September and December, when monthly rainfall ranges from 38 to 51 cm (Riffe 1987). Mean monthly air temperature varies from -2.4°C in January to 11.9°C in July (Riffe 1987).

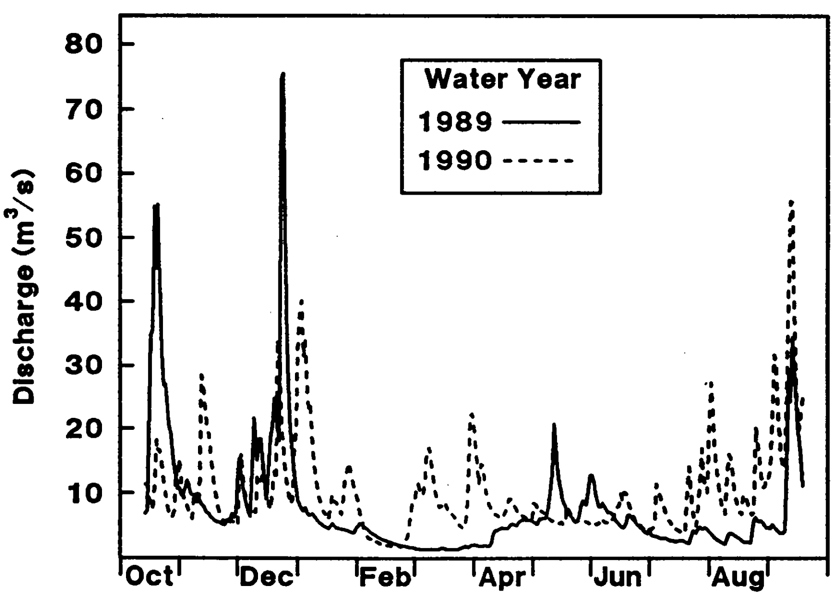

Figure H.5—Mean daily discharge of the Situk River, Alaska, in water years 1989 and 1990. Data are from Lamke et al. 1990, 1991.

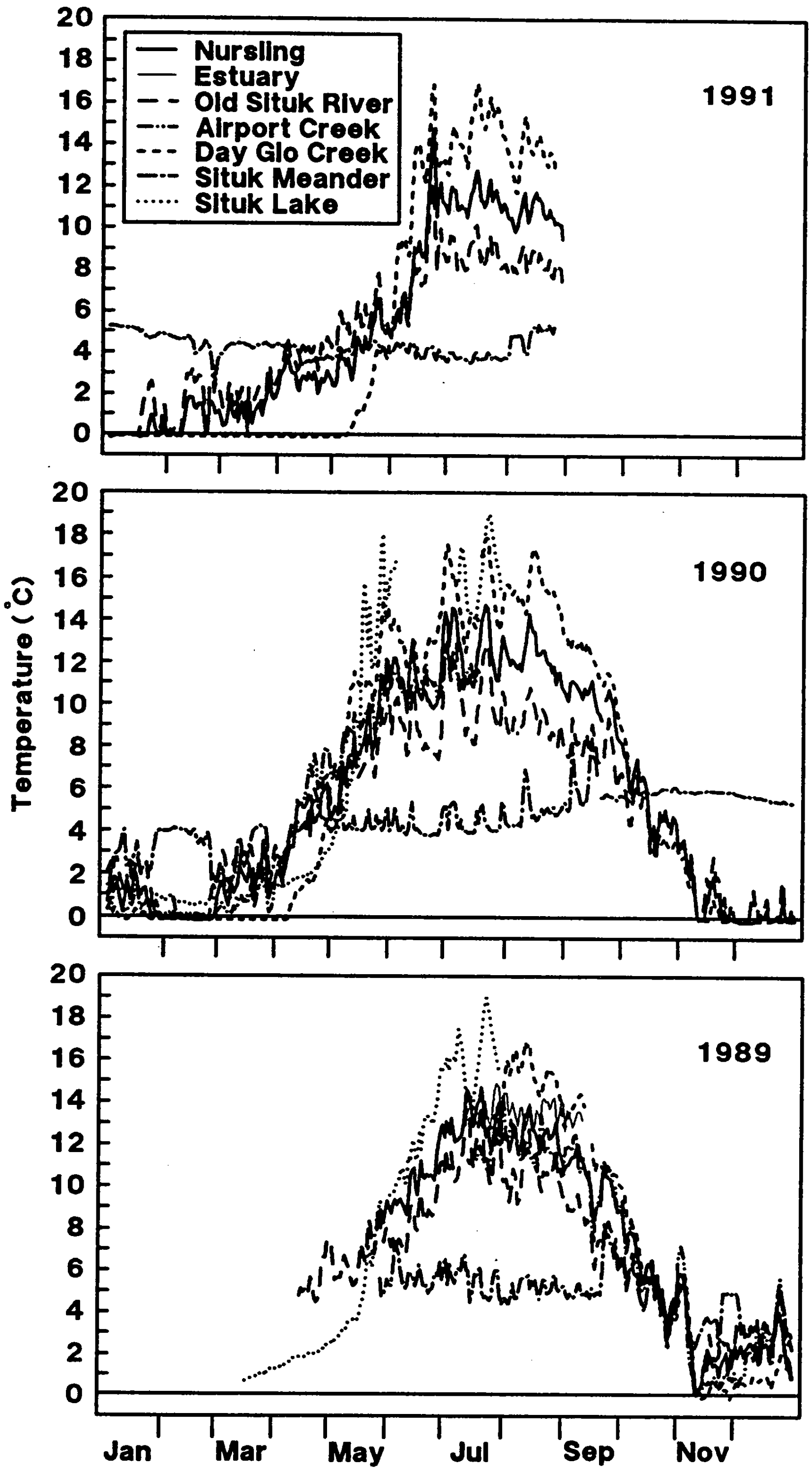

Figure H.6—Mean daily water temperature at seven locations, in the Situk and Lost River watersheds and the Situk estuary, 1989-1991 (USGS DATAPOD data not included).

STATUS OF STOCKS AND FISHERIES

Five species of Pacific salmon (*Oncorhynchus* spp.), steelhead trout (*O. mykiss*), Dolly Varden char (*Salvelinus malma*), eulachon (*Thaleichthys pacificus*), and Pacific lamprey (*Lampetra tridentata*) are indigenous to the Situk River. For the past 60 years, the annual return (harvest and escapement) of anadromous fish to the Situk River has been about 450,000 fish; over one-third is harvested in commercial, subsistence, and sport fisheries[2]. Sport anglers also catch and release several thousand fish annually (Johnson and Marshall 1991).

The annual total return of sockeye (*O. nerka*) to the Situk River is recovering from depressed levels. From 1934 to 1955, the total sockeye return averaged about 240,000 fish (110,000 harvest and 130,000 escapement), whereas the return from 1980 to 1989 averaged about 111,000 fish (36,000 harvest, 75,000 escapement)[2]. After the sockeye escapement goal was lowered in 1987 (from 80,000-100,000 fish to 40,000-55,000 fish; McPherson et al. 1987), harvest more than doubled (1987-89 mean, 71,858 fish; Didier and Marshall 1991) and the escapement goal has been reached or exceeded[2]. Thus, recent harvests of sockeye are similar to before 1955. Sockeye account for over one-half of the annual commercial salmon harvest in terminal Situk River gill-net fisheries (Bethers and Ingledue 1989) and about one-half of the dollar value[3]. Each year, subsistence fisheries harvest up to 3,000 sockeye (Didier and Marshall 1991), and sport fisheries harvest about 700 in the Situk River (Bethers and Ingledue 1989).

In the past decade, the annual total return of coho salmon (*O. kisutch*) to the Situk River averaged about 60,000 fish, of which about 30,000 fish were harvested: 20,000 in terminal gill-net fisheries and about 10,000 in commercial troll fisheries. The escapement goal for coho is 10,000-20,000 fish[4]. Coho account for about one-third to one-half of the commercial salmon harvest in terminal Situk River fisheries (Bethers and Ingledue 1989) and about one-half of the dollar value[5]. Annually, up to 1,600 coho are also harvested in subsistence fisheries (Didier and Marshall 1991), and about 1,800 fish in sport fisheries (Bethers and Ingledue 1989).

From 1980 to 1989, the total annual return of pink salmon (*O. gorbuscha*) to the Situk River averaged about 142,000 fish in even years and 265,000 fish in odd years[2]. These returns have been four times larger than between 1934 and 1955[2]. Low prices limit the commercial harvest of pinks, and harvest is mostly incidental to the gill-net sockeye fishery. Since 1934, an average of only 15,000 pinks have been harvested annually[2]. About 1,500 pinks are caught yearly in sport fisheries (Bethers and Ingledue 1989).

The annual total return of chinook salmon (*O. tshawytscha*) to the Situk River has declined in recent years. From 1980 to 1988, the return averaged about 2,000 fish (Bethers and Ingledue 1989) compared to 2,800 fish from 1933 to 1970 (Riffe 1987). Attempts to increase the return by curtailing harvest have been successful; escapement in 1992 was about 1,500 chinook[4, 5]. About 500 chinook are harvested annually in terminal fisheries (Bethers and Ingledue 1989), and about 5% of the annual return is probably taken in off-shore troll fisheries[6]. About 100 chinook

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[2]Unpubl. data. Alaska Dep. Fish and Game, Commercial Fisheries Div., P.O. Box 49, Yakutat, AK 99689.

[3]Unpubl. data. U.S. Forest Service, Yakutat Ranger District, Yakutat, AK 99869.

[4]Leon Shaul, Alaska Dep. Fish and Game, Commercial Fisheries Div., 802 Third St., Douglas, AK 99824. Pers. commun., Nov. 1991.

[5]Keith Weiland, Alaska Dep. Fish and Game, Commercial Fisheries Div., P.O. Box 49, Yakutat, AK 99689. Pers. commun., Oct. 1992.

[6]Sam Bertoni, Alaska Dep. Fish and Game, Fisheries Rehabilitation and Enhancement Div., Coded-wire Tag Processing Lab., P.O. Box 3-2000, Juneau, AK 99802-2000.

are harvested annually in subsistence fisheries, and another 135 fish are taken in sport fisheries (Bethers and Ingledue 1989; Didier and Marshall 1991).

Few chum salmon (*O. keta*) return to the Situk River, and few are harvested in terminal fisheries (Pahlke and Riffe 1988). Only about 500 chums return annually, and about 240 are harvested[2].

Recent returns of steelhead to the Situk River have averaged about 5,000-6,000 fish, considerably fewer than in the past: in 1952, over 20,000 steelhead returned (Knapp 1952). Both spring and fall races are present. The annual escapement of spring steelhead has averaged about 4,000 fish (Jones 1983; Johnson 1990, 1991); escapement of fall steelhead is probably less than 1,500 fish (Jones 1983; Johnson 1990). Annually, about 200 steelhead are harvested in terminal fisheries (Didier and Marshall 1991; Johnson and Marshall 1991), but harvests in other fisheries are unknown. From 1985 to 1990, the annual sport catch (harvest and catch-and-release) of steelhead averaged 3,500 fish (Johnson and Marshall 1991).

The Situk River supports a substantial run of anadromous Dolly Varden, although no estimates of total return are available. The annual sport catch of Dolly Varden averages about 1,000 fish, many caught incidentally by anglers targeting salmon and steelhead (Schwan 1984).

Tens of thousands of eulachon ascend the Situk River each year to spawn, and some are harvested for recreation and subsistence. Recreational harvest of eulachon in 1979 was about 1,500 fish (Schwan 1984), and the present annual combined recreation and subsistence harvest is estimated to be about 4,000 fish.

The Situk estuary is utilized by a wide variety of fish species, including the anadromous species described above and marine species, such as Pacific staghorn sculpin (*Leptocottus armatus*), starry flounder (*Platichthys stellatus*), threespine stickleback (*Gasterosteus aculeatus*), Pacific sand lance (*Ammodytes hexapterus*), Pacific herring (*Clupea pallasi*), arrowtooth flounder (*Atheresthes stomias*), Pacific prickleback (*Lumpenus sagitta*), sand sole (*Psettichthys melanostictus*), greenling (*Hexagrammos superciliosus*), and surf smelt (*Hypomesus pretiosus*). Crustaceans include Dungeness crab (*Cancer magister*). Other than the anadromous species and Dungeness crab, these species have little commercial or sport value. A more complete description of the fauna present in the estuary is provided in Study 8.

Anadromous fish that utilize Russell Fiord streams include primarily Dolly Varden, coho salmon, and pink salmon. Other fishes present in the streams include threespine stickleback and sculpins (*Cottus* sp.). Commercially important marine fish, crustaceans, and mollusks that occur in Russell Fiord include Pacific halibut (*Hippoglossus stenolepis*), Tanner crab (*Chionoecetes bairdi*), red king crab (*Paralithodes camtschaticus*), blue king crab (*P. platypus*), spot shrimp (*Pandalus platyceros*), and weathervane scallops (*Pecten caurinus*)[7].

LIFE HISTORIES

Life Stage and Stock Designations of Anadromous Fish

The life stages of juvenile salmonids are termed smolt, presmolt, parr, or fry throughout this report. Smolts are juveniles that are physiologically capable of adapting to seawater and have distinct morphological characteristics (e.g. silvered body, darkened fin tips) (Trautman 1973). We

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[7]Keith Weiland, Alaska Dep. Fish and Game, Commercial Fisheries Div., P.O. Box 49, Yakutat, AK 99689. Pers. commun., April 1992.

define parr as fish that have reared one or more years in fresh water (one or more annuli) and do not have smolt morphological characteristics. Presmolts have characteristics intermediate between smolts and parr. We define fry as fish that have reared less than a year in fresh water (emergence to first annulus).

Some sockeye and most chinook in the Situk River migrate to sea as fry (Studies 4 and 5). Fish with this uncommon life history are sometimes referred to as sea-type (Wood et al. 1987), ocean-type (Meehan and Bjornn 1991), age-0, or zero-check (McPherson et al. 1988) sockeye and fall or ocean-type chinook (Healy 1983). In this report, sockeye and chinook that migrate to sea as fry are called ocean type.

Sockeye

Life history of Situk River sockeye varies depending on location. Freshwater residence of juveniles ranges from a few days to 4 years. In Old Situk River, about 70% of juveniles are ocean type (Study 6); in Situk Lake, juveniles rear 1-2 years in fresh water before migrating to sea (60% stay 1 year, 40% stay 2 years; Rowse 1990); sockeye that rear 1 or more years in a lake are called "lake-type" (Wood et al. 1987). In Mountain Lake, 95% of juveniles rear 2-3 years in fresh water before migrating to sea (Rowse 1990). Most (95%) sockeye from the Situk River spend 2-3 years at sea.

Chinook

Chinook in the Situk River have a unique life history for Alaska—most juveniles are "age 0". In most other Alaska streams, chinook rear in fresh water at least 1 year before migrating to sea (Kissner 1986; Healey 1983). Chinook usually spend 3-4 years at sea.

Coho

Coho life history in the Situk River is similar to that in other Alaska streams. Coho typically spend 1-2 years in fresh water and about 18 months at sea. Most (95%) coho smolts in Old Situk River are age 1 (Study 6), whereas most (56%) coho smolts from the remainder of the watershed are age 2 and 3 (Study 7).

Pink and Chum

Pink and chum salmon in the Situk River exhibit life histories common to Alaska. Freshwater rearing is unimportant because juveniles of both species migrate to sea soon after emergence. Pinks return to spawn after one winter at sea, whereas chum spend 3-4 years at sea.

Steelhead

Juveniles of both spring and fall steelhead spend 2-4 years in fresh water. Juvenile fall steelhead rear in fresh water longer than spring steelhead; nearly 50% of fall fish spend at least 3 years in fresh water, whereas less than 25% of spring fish rear for that long (Jones 1983). Both races spend 2-5 years at sea, and about 25% of the total run are repeat spawners (Jones 1983).

Dolly Varden

Information is scarce on Dolly Varden in the Situk River. Adult Dolly Varden probably enter the Situk River in spring and summer to feed on salmon eggs and fry, as they do in other Alaska streams (Armstrong 1965a). Adult Dolly Varden ascend the river in fall to spawn and winter in lakes, as in other rivers in Southeast Alaska (Armstrong 1965a). Dolly Varden typically spend 3-4 years in fresh water before migrating to sea as smolts (Blackett 1968).

Eulachon

Little is known about the life history of Situk River eulachon. Elsewhere, eulachon typically spend little time in fresh water; adults spawn over a 4-week period in spring, and eggs incubate in streams for about 3 weeks (Hart and McHugh 1944). Larvae enter the ocean soon after hatching, and juveniles spend at least 3 years at sea before maturing and returning to spawn (Clemens and Wilby 1961).

A more detailed description on the migration timing of adults and juveniles, spawning, and incubation requirements of all species is provided in Studies 1, 4, 5, 6, and 7.

REASONS FOR SITUK RIVER PRODUCTIVITY

The Situk River is one of the most productive rivers in Southeast Alaska. One aspect of this productivity is high species diversity: five species of Pacific salmon, two races of steelhead, Dolly Varden, and ocean-type stocks of chinook and sockeye. Another aspect is the high density of juvenile salmonids in many stream reaches. In this section, we examine possible reasons for the Situk River's high productivity.

The Situk River's high productivity is displayed primarily by stream-rearing salmonids. Summer densities of juvenile coho in flood-plain areas (FP channel type; Paustian 1992), for example, are 6-22 times greater than the average density in such areas in other Southeast Alaska streams (Table H.1). Summer density of Dolly Varden in the FP4 channel type (in Old Situk River) was 6 times greater than average for Southeast Alaska, but Dolly Varden density in the FP3 and FP5 channel types was less than average. Steelhead are abundant in many stream reaches, particularly the West Fork, whereas steelhead are absent from many Southeast Alaska streams (Johnson et al. 1986).

Unlike the riverine habitats, Situk and Mountain Lakes are not unusually productive. Although chemical analysis indicates high conductivity of water in these lakes (Schmidt 1981), plankton and fish populations are not exceptional. Production of sockeye smolts from Situk, Mountain, and Redfield Lakes totaled about 700,000 fish in 1990 (Study 7), which is less than the estimated production capacity of 960,000 smolts, based on the euphotic-volume model of Koenings and Burkett (1987) (Table H.2). Zooplankton biomass in the lakes, furthermore, was near the low end of the spectrum of selected lakes in Alaska[8]. Mountain Lake ranked 18 and Situk Lake ranked 23 out of 25 lakes surveyed (Table H.3). The low zooplankton biomass may have been the result of high escapements of adult sockeye in previous years, producing too many fry for the available food base[7, 8].

The extraordinary productivity of Situk riverine habitats could stem from a combination of favorable hydrologic, topographic, and geologic factors, including 1) stable hydrologic regime and high baseflow, which result from the river's substantial groundwater inflow and attenuating effects of headwater lakes; 2) flat topography and low-gradient stream channels, which facilitate formation of pool habitat; 3) warm summer temperature, which may result from the presence of headwater lakes and the watershed's southern aspect; and 4) high food production, which may result from high levels of available nutrients and good exposure to sunlight.

Probably the most important factor in the Situk River's high productivity is the river's stable hydrologic regime. Compared to other streams and rivers in Southeast Alaska, the Situk

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[8]Dave Barto, Alaska Dep. Fish and Game, Div. Fisheries Rehabilitation, Enhancement, and Development, Southeast Region (1), 802 Third St., Douglas, AK 99824. Pers. commun., Feb. 1992.

River's discharge is quite stable. The ratio of the river's maximum and minimum flows was the smallest of 15 streams and rivers monitored by the USGS in 1990 (Table H.4). Maximum flow in the Situk River in 1990 was only 34 times the minimum flow; the ratio in the other streams ranged from 43 to 6,400. Attenuation of extremes in discharge probably reduces mortality of juvenile salmonids in fall and winter (Murphy et al. 1984).

Table H.1—Comparison of summer densities (no./100 m^2) of juvenile coho and Dolly Varden by channel type in the Situk River (Study 2) and the mean density in other streams in Southeast Alaska*.

Channel Type	Coho		Dolly Varden	
	Situk	Other	Situk	Other
FP3	203	35	17	34
FP4	278	30	170	29
FP5	176	8	1	19

*Steve Paustian, USDA Forest Service, Region 10, 204 Siginaka Way, Sitka, AK 99835. Pers. commun., Oct. 1991.

Table H.2—Area, euphotic depth, and predicted production capacity for sockeye salmon fry, smolts, and adults for some Southeast Alaska lakes, based on the euphotic-volume model of Koenings and Burkett (1987) and fry survival rates in winter observed by Kyle (1990)[7, 8].

Lake	Area (km^2)	Euphotic Depth (m)	Predicted Smolts (millions)	Predicted Adults (thousands)
Situk	**4.1**	**10.2**	**0.96**	**104**
Mountain	**0.8**	**12.0**	**0.28**	**30**
Crescent	3.3	9.1	0.99	75
Chilkoot	7.0	6.5	1.05	114
Chilkat	9.8	17.5	3.95	429

Table H.3—Comparison of mean (May-October) zooplankton density and biomass in some Alaska lakes[7, 8].

Lake	Density (thousands/m^2)	Biomass (mg/m^2)
Chenik	727	2,027
Hidden	570	1,939
Chelatna	633	1,902
Chilkat	696	1,349
Karluk	518	915
Eshamy	288	691
Packers[a]	194	625
Skilak	208	564
Hugh Smith	177	380
McDonald[a]	100	336
Leisure[a]	215	335
Bakewell	178	246
Chilkoot	139	191
Redoubt[a]	144	156
Afognak	153	154
Crescent	88	153
Coghill	64	127
Mountain	**112**	**117**
Frazer	88	114
Virginia	88	111
Tustumena	37	99
Redoubt[b]	94	85
Situk	**117**	**77**
Leisure[b]	49	53
English Bay	48	23

[a]Fertilized.

[b]Pre-fertilization.

Table H.4—Minimum and maximum daily discharge (m^3/s) of Southeast Alaska streams monitored by the USGS in 1990 (Lamke et al. 1991). Streams are listed in order of increasing minimum baseflow. The month of minimum flow is in parentheses.

Stream	Minimum	Maximum	Ratio Max/Min
Gold Creek (Jan)	0.01	64.0	6,400
Perkins Creek (Jul)	0.02	24.7	1,235
Old Tom Creek (Jul)	0.03	24.2	807
Greens Creek (Feb)	0.2	40.5	202
Salmon Creek (Feb)	0.2	16.4	82
Hamilton River (Jul)	0.2	264.6	1,323
Kadashan River (Jul)	0.2	27.9	140
Indian River (Feb)	0.4	161.8	404
Staney Creek (Aug)	0.4	317.4	793
Situk River (Feb)	**1.8**	**60.3**	**34**
Harding River (Feb)	2.0	161.5	81
Farragut River (Feb)	2.8	447.7	160
Klehini River (Feb)	3.6	255.0	170
Taku River (Feb)	34.0	2,244	66
Stikine River (Feb)	156.8	6,772	43

Another beneficial feature of the Situk River's hydrologic regime is a high baseflow in summer and winter. As with most mainland streams in Southeast Alaska, the Situk River's minimum flow is in February; most island streams' minimum is in July (Lamke et al. 1990). The Situk River's minimum flow of 1.8 m^3/s in February 1990 was higher than the minimum discharge of nine other streams monitored by the USGS in 1990 (Table H.4). The Situk River's summer minimum, furthermore, was 4.0 m^3/s in 1990, which was much higher than the summer baseflow of any of the monitored island streams. The streams with higher minimum baseflow than the Situk River were mainland rivers with glacial influence and much larger watersheds. Thus, the Situk River's baseflow is unusually high for a watershed of its size. Heavy rainfall, abundant groundwater, and attenuating effects of headwater lakes help maintain the river's high baseflow. Minimum streamflows are often critical for rearing juveniles (Bjornn and Reiser 1991), and the Situk River's high baseflow could help explain the river's high productivity.

Flat topography probably also contributes to the great abundance of stream-rearing salmonids in the Situk River because of the preponderance of flood-plain and palustrian stream channels. The Situk River's average gradient is 0.6%, which is low compared to many other streams in Southeast Alaska (Paustian 1992). Almost all segments of the Situk River and its tributaries are either flood-plain (61% by length) or palustrian (39%) channel types. Other Southeast Alaska watersheds typically have large components of erosional and transportational channels that have lower habitat capability for salmonids (Paustian 1992).

Stream temperature does not appear to be a principal cause of the unusual productivity of the Situk River. Comparison of temperature regimes with five other Southeast Alaska streams monitored by the USGS (Lamke et al. 1990, 1991) showed that the Situk River is about average (Table H.5). Maximum temperature in July 1990 was 18.0°C, in the middle of the range for Southeast Alaska streams; minimum July temperature was 10.5°C, on the low end of the range measured by the USGS. Maximum in January 1990 was 2.5°C, lower than four of the other five gauged streams; minimum was 0.0°C, the same as the other streams.

Water quality is another possible factor in the river's high productivity. Compared to some other Southeast Alaska streams, the Situk River has higher pH, conductivity, and alkalinity (Table H.6). Because alkalinity commonly results from dissolution of sedimentary carbonate rocks, the comparatively high alkalinity in the Situk River indicates an abundance of sedimentary rock, probably derived from uplifted marine deposits. Alkalinity is an index of aquatic productivity, being directly related to aquatic primary production (Cole 1979). Thus, relatively high alkalinity and primary productivity could contribute to the Situk River's high fisheries productivity by increasing the available food base.

Concentrations of the important inorganic nutrients (phosphate and nitrate) were not any greater than in other Southeast Alaska streams (Table H.6). Water samples, however, often do not indicate actual amounts of available phosphate because aquatic bacteria and algae rapidly withdraw it from the water (Cole 1979). Based on the Situk River's high alkalinity, phosphate is probably abundant because it is, like alkalinity, commonly derived from sedimentary carbonate rocks (Golterman 1975).

In conclusion, the Situk River's unusually high salmonid productivity is most evident in stream-rearing populations; lake-rearing populations are average. The productivity of the stream habitat probably derives primarily from the river's stable hydrologic regime, high baseflow, and low gradient. High levels of dissolved nutrients also may contribute to the productivity.

Table H.5—Comparison of maximum and minimum water temperature (°C) in January and July in Southeast Alaska streams monitored by the USGS in 1989 or 1990 (Lamke et al. 1990, 1991).

		January		July	
Stream	Year	Max	Min	Max	Min
Situk	**1990**	**2.5**	**0.0**	**18.0**	**10.5**
Kadashan	1989	1.0	0.0	15.0	10.5
Hamilton	1990	3.0	0.0	22.5	12.5
Old Tom	1990	5.0	1.0	17.0	11.0
Perkins	1989	3.5	0.0	18.0	12.0
Staney	1990*	3.0	0.0	25.5	15.0

*Partial data.

Table H.6—Comparison of water quality characteristics of the Situk River and some other Southeast Alaska streams.

Stream	pH	Conductivity[a]	Alkalinity[b]	Phosphate[c]	Nitrate[d]
Situk[e]	**7.4**	**123**	**59**	**<0.010**	**<0.100**
Kadashan[e]	7.0	64	20	—	—
Hamilton[e]	6.7	24	10	—	—
Old Tom[e]	6.2	44	14	0.010	<0.100
Perkins[e]	6.0	27	4	<0.010	<0.100
Sunny[f]	—	—	44	<0.005	0.080
Black Bear[f]	—	—	30	0.006	<0.050
Wheeler[f]	—	—	40	0.017	0.080
King Salmon[f]	—	—	14	0.025	<0.050
Freshwater[f]	—	—	53	0.018	0.103
Castle[f]	—	—	10	0.010	0.060
Wasta[f]	—	—	6	0.011	0.080

[a] µmho/cm.

[b] mg $CaCO_3$/L.

[c] mg P/L.

[d] mg N/L.

[e] Lamke et al. (1991).

[f] Murphy et al. (1987); means of 3-6 different channel types per stream.

STUDY 1.

SPAWNING OF ANADROMOUS FISH IN THE SITUK RIVER

Rationale

Adult anadromous fish migrate and spawn in areas of the Situk River that will be flooded when Russell Fiord overflows. To determine how flooding may affect anadromous fish, the extent of habitat use by adult fish in areas that would be flooded must be assessed.

Objectives

Objectives of this study were to determine migration timing, residence time in the main-stem flood zone, spawning distribution, and abundance of adults of all species of anadromous fish species in the Situk River; describe migration and spawning habitats of adult sockeye, chinook, and pink salmon; and describe egg incubation of all anadromous fish.

Summary of Results

All anadromous fish that return to the Situk River must enter the predicted flood zone to migrate to spawning areas. The maximum proportion of each species' escapement that is in the flood zone at one time varies greatly, ranging from about 90% of chinook to less than 10% of fall steelhead. About one-half of the total anadromous fish escapement to the Situk River spawn in the flood zone; however, the most economically important species (sockeye, coho, chinook, and steelhead) spawn mainly outside the flood zone. Ocean-type sockeye and eulachon are most vulnerable to flooding because their spawning habitat is almost entirely inside the flood zone.

METHODS

Results of this study are from NMFS field studies, published and unpublished records, and consultation with fisheries personnel from other agencies.

Adult Migrations

Time of adult entry into the Situk River was determined for each anadromous species. Entry timing of sockeye, chinook, pink, and coho salmon was obtained from Riffe (1987). Entry timing of chum salmon, steelhead, Dolly Varden, and eulachon was estimated from published and unpublished data, personal communications, and personal observations.

Residence time in the flood zone of the main-stem Situk River (between Forest Highway 10 and the boat landing at the end of Lost River Road; Fig. H.4) was estimated for each anadromous species. Residence time of sockeye and chinook was estimated by tagging and tracking adult fish. Residence time of pinks, chum, steelhead, Dolly Varden, and eulachon was inferred from published data, personal communications, and personal observations.

Adult sockeye and chinook were tagged at the adult salmon weir in the main-stem Situk River (Fig. H.4) between 14 June and 21 August 1988. Sockeye were tagged with spaghetti tags, and chinook were tagged with Petersen disc tags. The total run was divided into three periods: early, 7 June–7 July; middle, 8–25 July; and late, 26 July–22 August. A different tag color was used in each period. About 10% of all sockeye and chinook salmon were tagged, but the escapement and the percentage of the escapement tagged differed between periods (Table 1.1). Because of the small number of tagged chinook, radio transmitters were orally inserted into stomachs of 30 disc-tagged chinook to improve tracking (Fig. 1.1).

Surveys of the flood zone in the main-stem Situk River were conducted by boat every other week between 14 June and 8 August to observe fish and determine habitat use. During each survey, tagged fish were counted and numbers of pink salmon were visually estimated. Where groups of sockeye (>10 fish), pink salmon (>20 fish), or any chinook were found, we recorded habitat type (pool, riffle, or glide), water depth (mean of three or more measurements), and amount (absent, common, or abundant) of cover (i.e., overhanging or submerged riparian vegetation and large woody debris [LWD]). Habitat of other species was inferred from the literature, personal communications, and personal observations.

Because only some of the tagged fish were observed during each survey, the number of tagged fish actually in the survey area was estimated. We expanded the observed number of tags by our observation efficiency ($\hat{a}$), which we estimated from the proportion of tagged fish observed during the first survey when all tagged fish were assumed to be within the survey area. Observation efficiency was calculated from the equation

$$\hat{a} = \frac{n_1}{x_1}, \tag{1}$$

where $\hat{a}$ is observation efficiency, n_1 is the number of tagged fish observed in the first survey of the tagging period, and x_1 is the cumulative number of fish tagged up to that first survey. Observation efficiency was estimated separately for each species each tagging period. We assumed that observation efficiency was constant during the tagging period. The number of tagged fish in the survey area was estimated for each species and tagging period by the equation

$$\hat{n}_i = \frac{n_i}{\hat{a}}, \tag{2}$$

where $\hat{n}_i$ is the estimated number of tagged fish in the survey area at survey i, and n_i is the number of tagged fish observed during survey i.

The proportion of tagged fish from each tag group remaining in the survey area was calculated by the equation

$$\hat{P}_i = \frac{\hat{n}_i}{x_i}, \tag{3}$$

where $\hat{P}_i$ is the proportion of tagged fish remaining in the survey area at survey i, and x_i is the cumulative number of fish tagged up to survey i.

To estimate $\hat{P}$ for any given date between surveys, we regressed $\hat{P}$ on day of the year (day 1 = 1 January), using arcsin transformation (Sokal and Rohlf 1969) of $\hat{P}$ to linearize the regressions (Table 1.2). To estimate the total number of fish (tagged and untagged) remaining in the survey area on a given day, $\hat{P}$ from the regressions was multiplied by the cumulative number of fish counted at the Situk River weir up to that date:

$$\hat{N}_d = \hat{P}_d I_d \,, \tag{4}$$

where $\hat{N}_d$ is the estimated total number of fish in the main-stem flood zone on day *d*, $\hat{P}_d$ is the estimated proportion of tagged fish in the survey area on day *d*, and I_d is the cumulative number of fish counted at the Situk River weir up to that date. From $\hat{N}_d$, we estimated the median residence time as the number of days for 50% of the total escapement during a tagging period to emigrate from the main-stem flood zone.

Spawning Distribution and Habitat

Spawning distribution of sockeye, chinook, and pink salmon was estimated from surveys of the Situk River, West Fork, Old Situk River, and Mountain Stream (Fig. H.4) between 14 June and 30 September 1988. Surveys were by boat, foot, and fixed-wing aircraft until 14 September and by aircraft thereafter. During surveys, habitat characteristics at fish concentrations, counts of tagged fish, approximate numbers of pink salmon, and observations of other anadromous fish were recorded on maps. Spawning distributions of other species were estimated from published and unpublished data, personal communications, and personal observations.

Spawning habitat of sockeye and chinook was observed in 19 stream reaches containing isolated groups of redds. Within these reaches, 45 individual redds (26 sockeye and 19 chinook) and 18 multiple (overlapping) redds (5 sockeye and 13 chinook) were identified, and habitat characteristics (intragravel temperature, water temperature, water depth, and water velocity) were measured at each redd (Fig. 1.2). At the individual redds, we also measured maximum length and width of the redd and visually estimated percentage of three substrate size classes (fine, <2 mm; gravel, 2-100 mm; and coarse, >100 mm) in the bowl and tailspill of the redd.

Incubation

Incubation period was estimated for each anadromous species, based on approximate dates of peak spawning and peak emergence. Peak spawning dates were derived from surveys of tagged adults and ADF&G spawning surveys. Peak emergence dates were estimated from observations of emergent fry in the Situk River from 1988 through 1990 (Studies 3, 5, 7, and 9). Thermograph data from five sites in the Situk River (Fig. H.6) were used to determine the cumulative number of temperature units (T) recorded at those sites during incubation; one temperature unit equals one degree-day above 0°C. The mean number of temperature units ($\bar{T}$) needed for emergence of each species was estimated as the sum of the weighted T from each thermograph:

$$\bar{T} = \sum_{k=1}^{5} S_k T_k \,, \tag{5}$$

where (S_k) is the proportion of spawners nearest to or best represented by thermograph *k*.

RESULTS AND DISCUSSION

Most adult anadromous fish enter the Situk River to spawn between early March and mid-September; an exception is fall steelhead, which enter the river primarily in October and November[9] (Fig. 1.3). Entry timing and habitat use overlap among several species. Tagging in 1988 showed that some adults moved steadily upstream through the main-stem Situk River, whereas others held in the same area for several weeks. The maximum percentage of adult escapement in the flood zone at any given time differs among species, ranging from nearly 90% for chinook (Fig. 1.4) to less than 10% for fall steelhead. In the flood zone, most migrating fish held in pools or deep (>1 m) glides along banks with overhanging or submerged vegetation.

Anadromous fish spawn throughout the Situk River watershed. The percentage of fish spawning in the flood zone ranges from 0% of fall steelhead to 100% of eulachon (Fig. 1.5). In 1988, about one-half of the entire escapement spawned within the flood zone, and eggs incubated there every month of the year (Fig. 1.6). Most (85%) fish that spawned within the flood zone were pink salmon or eulachon; many coho, steelhead, and Dolly Varden, however, also spawned there. Species usually spawned in different areas, and each species used different spawning habitat (Appendix 1).

Sockeye Salmon

Most adult sockeye entering the Situk River in 1988 migrated rapidly from salt water to lakes, or stream sections near lakes, and remained there until they spawned, the usual migration pattern for most lake-type sockeye (Bevan 1962; Ricker 1966; Foerster 1968). Most stream-spawning sockeye used spawning habitat similar to that of sockeye in other streams (Foerster 1968; Leman 1988): shallow, low-velocity water, variable substrate, and close proximity to lakes. Ocean-type sockeye in the Situk River, however, used habitat similar to ocean-type sockeye in the Taku River where they use holding areas in the main stem during upstream migration and spawn in areas with upwelling groundwater (Lorenz and Eiler 1989).

Migration of adult sockeye into the Situk River begins in mid-June, peaks in early July, and declines steadily through late August (Riffe 1987; Fig. 1.3). Based on 1988 tagging, sockeye were most numerous in the main-stem flood zone in July (Fig. 1.4), when about 40% of the escapement was present.

Based on models of the 1988 sockeye migration (Fig. 1.7; Table 1.2), median residence time of sockeye in the main-stem flood zone was 17.3 days, but differed between periods. Sockeye tagged in the early period of the run remained in the flood zone significantly ($P < 0.02$; Scheffé's test) longer (median, 34.2 days) than sockeye tagged in the late period (median, 10.6 days). Most (95%) sockeye tagged in the early period migrated out of the flood zone by 1 August, whereas most tagged in the middle and late periods left the flood zone by 10 August. Migrating sockeye primarily were in deep (>1 m) glides near pools formed by LWD or glides with overhanging or submerged vegetation.

In 1988, most sockeye spawned between late July and late September; many sockeye that spawned in lakes, however, could not be observed. Sockeye were first seen spawning in the main-stem Situk River 5 km upstream of Forest Highway 10 on 27 July, and a few were still spawning near the Situk Lake outlet during the final survey on 30 September. Spawning in streams peaked the second and third weeks of August.

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[9]Unpubl. data. Alaska Dep. Fish and Game, P.O. Box 49, Yakutat, AK 99689.

Sockeye bound for Mountain Lake in 1988 entered the Situk River earlier and emigrated from the main-stem flood zone significantly ($P < 0.01$; t-test) faster than the overall escapement. Mountain Lake sockeye made up about 50% (8,200 fish) of the 1988 escapement in the early period, 30% (5,100 fish) in the middle period, and 23% (3,900 fish) in the late period (Rowse 1990[10]). In the early and middle periods, Mountain Lake sockeye spent 14 and 15 days, respectively, between the weirs on the Situk River and Mountain Lake (Fig. H.4), and most (95%) fish tagged in the early and middle periods passed the Mountain Lake weir by 24 July and 16 August, respectively[11]. In the late period, Mountain Lake sockeye spent 22 days between weirs, and most passed the Mountain Lake weir by 2 September[7, 8].

In 1988, over 95% of the sockeye in the Situk River spawned in or near lakes. About 36% of the 1988 escapement spawned in Mountain Lake (Rowse 1990) and a smaller percentage in Situk Lake. Density of spawning in river habitat was greatest within 3 km downstream of Situk Lake. Many spawning sockeye also were observed in Mountain Stream and in the West Fork near Redfield Lake. Scattered spawning was observed in three other locations: the main-stem Situk River from 1 km downstream of the highway to 3 km downstream of Situk Lake; Old Situk River from the highway upstream 2 km; and sloughs along Old Situk River downstream of the highway (Fig. 1.8). Only about 5,000 sockeye spawned within the flood zone (Fig. 1.5), and (based on scale samples from sockeye in the Old Situk River[12]) about two-thirds of these probably were ocean type. Thus, most (>95%) ocean-type sockeye remained in the flood zone from the time they entered the Situk River until they spawned.

Of the sockeye that spawned in stream reaches in 1988, 65% used glides, 30% used pools, and 5% used riffles. Sockeye used an average of 3.7 m^2 of streambed for redds, in water averaging 49.6 cm deep and 26.5 cm/s in velocity. Substrate in redds averaged 23% fine sediment, 72% gravel, and 5% coarse sediment. Differences between surface water temperature (mean, 9.1°C) and intragravel temperature (mean, 6.2°C) indicated the presence of upwelling groundwater in spawning areas.

Sockeye eggs and alevins from the 1988 brood year incubated in the Situk River for about 250 days (Fig. 1.6); spawning peaked in mid-August, and fry emergence peaked in late April (Table 1.3). Incubation time in Old Situk River was about 10 days less than in the main stem; spawning peaked in late August, and emergence peaked in mid-April. During incubation, sockeye spawning areas downstream of Situk Lake received 1,245 temperature units ($\bar{T}$) with a mean temperature of 4.9°C, while those in Old Situk River received 820 temperature units ($\bar{T}$) with a mean temperature of 3.5°C; typically, sockeye incubating under similar conditions would require 800-865 temperature units to reach peak (50%) emergence (Table 1.3). Obviously, there was a large difference between the observed versus the predicted number of temperature units needed for sockeye emergence below Situk Lake. Thus, either the estimated incubation period was off by as much as a month on either end, there was a large difference between the temperature recorded by the thermograph and actual incubation temperature below Situk Lake, or some combination of the two.

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[10]For unknown reasons, the proportion of tagged fish in weir counts declined by 51% overall between the sites. Therefore, the preceding percentages may be inaccurate.

[11]Ben Kirkpatrick, Alaska Dep. Fish and Game, Div. Commercial Fisheries, P.O. Box 49, Yakutat, AK 99689. Pers. commun., Sept. 1988.

[12]Adam Moles, National Marine Fisheries Service, Auke Bay Lab., 11305 Glacier Hwy., Juneau, AK 99801. Pers. commun., Oct. 1989.

Chinook Salmon

The migration of adult chinook into the Situk River begins in mid-May, peaks in mid-June, and declines through mid-August (Riffe 1987; Fig. 1.3). In 1988, about 90% of adult chinook were in the main-stem flood zone in late July (Fig. 1.3). Chinook spent more time migrating through the main-stem flood zone than did sockeye. Based on models of chinook migration in 1988 (Fig. 1.7; Table 1.2), the median residence time of chinook in the main-stem flood zone was 29.8 days. Residence time was similar ($P > 0.1$; F test) among tagging periods.

As in other rivers (Hamilton and Buell 1976; Burger et al. 1985), chinook often held in large pools or deep glides until mature. Migrating chinook primarily used deep (>2 m), open pools or deep (>1 m) glides along banks with overhanging or submerged vegetation. Chinook that used deep glides usually moved upstream more steadily than chinook that held in pools. Individual chinook often held in the same pool for most of the time they were monitored in the flood zone, and then moved quickly (within 1 or 2 days) to spawning areas.

Chinook spawning was observed between 30 July and 14 September. Spawning was first observed on 30 July in the main stem 1.5 km upstream of the highway. Chinook spawning peaked about the first week of September and was finished before 30 September. On the last aerial survey on 30 September, no spawning chinook were seen, and most radio-tagged fish were dead.

As in other rivers (Smith 1973; Bjornn and Reiser 1991), chinook in the Situk River spawned in relatively deep, fast water and used large substrate. All chinook spawned either in riffles or glides. Chinook used an average of 19.0 m^2 of streambed to construct a redd. Spawning sites had mean water depth of 79.6 cm and mean water velocity of 73.0 cm/s. Substrate at redds averaged 5% fine sediment, 76% gravel, and 19% coarse sediment. Mean water temperature was 12.2°C and mean intragravel temperature was 11.9°C. All habitat characteristics differed significantly ($P < 0.05$; t test) from habitat of stream-spawning sockeye; chinook spawned in deeper, faster water, larger substrate, and less groundwater than sockeye.

About 95% of tagged chinook survived to spawn, and 90% of survivors spawned in the main stem between the highway and Situk Lake (Fig. 1.9). Some tagged chinook also spawned in the main stem within 1 km downstream of the highway and in the lower 1 km of the West Fork. Chinook without tags were seen spawning in the main stem within 3 km downstream of the highway and in Mountain Stream (Fig. 1.9). Only about 5% of chinook spawned in the flood zone.

Brood-year 1988 chinook salmon eggs and alevins incubated for about 235 days in the Situk River (Fig. 1.6); spawning peaked in early September, and emergence peaked in late April (Table 1.3). During incubation, chinook spawning areas received 924 temperature units ($\bar{T}$) and had a mean temperature of 3.9°C (Table 1.3).

Pink Salmon

Migration of adult pink salmon into the Situk River begins in early July, peaks in early August, and declines steadily through early September (Riffe 1987; Fig. 1.3). In 1988, pinks were most numerous in the main-stem flood zone from mid-July to mid-August (Fig. 1.4), when 20-25% of the escapement (30,000-40,000 fish) was present there. Migrating pinks were primarily in glides with overhanging vegetation or in tails of pools. Pinks apparently migrated directly to spawning areas, which is similar to behavior in other coastal streams (Ishida 1966; McNeil 1966; Heard 1978).

In 1988, pinks spawned from mid-August to early September with peak spawning in late August. Spawning was first observed on 10 August about 10 km upstream of the boat landing, and last observed on 8 September near the boat landing. Pinks spawned in three main areas: the main stem, from about 7 km upstream of the boat landing to 4 km downstream of Situk Lake; the Old Situk River, from its mouth to 1 km downstream of the highway; and in the West Fork (Fig. 1.10). In most years, about 40% of pinks (60,000 fish) spawn within the flood zone (Fig. 1.5). Pinks in the Situk River used similar spawning habitat as in other streams (Neave 1966; Bjornn and Reiser 1991): shallow (<40 cm) open glides or tails of pools.

Brood-year 1988 pink salmon eggs and alevins incubated for about 245 days in the Situk River (Fig. 1.6); peak spawning was in late-August and peak emergence was in early-May (Table 1.3). During incubation, pink salmon spawning areas received 790 temperature units ($\bar{T}$) and had a mean temperature of 3.2°C (Table 1.3).

Coho Salmon

Coho salmon are one of the most numerous and economically important species in the Situk River, yet relatively little is known about their escapement and spawning distribution (Pahlke and Riffe 1988). Data on coho escapement is incomplete because the timing of fisheries, weir counts, and stream surveys does not include the entire escapement and spawning periods[13]. Generally, coho in the Situk River migrate to spawning areas during high stream flow in fall and spawn throughout the watershed.

Migration of coho salmon into the Situk River begins in early August and peaks in early September (Riffe 1987; Fig. 1.3). Coho are most numerous in the main-stem flood zone in early September (Fig. 1.4), when about 25% of the total escapement (about 8,000 fish) are present there. Stream surveys indicate that coho escapement declines slowly from mid-September through mid-October[2,4,5].

Coho spawning in the Situk River begins in mid-September and continues through December[2,4,5]. Spawning coho have been observed in the main stem from 3 km downstream of Situk Lake, Old Situk River, West Fork, Mountain Stream[2], and many tributaries[14] (Fig. 1.11). Stream surveys indicate that 20-30% of coho spawn within the flood zone[2] (Fig. 1.5). Spawning habitat was not measured, but general habitat characteristics are summarized in Appendix 1.

Coho eggs and alevins incubate for about 210 days in the Situk River (Fig. 1.6), based on peak spawning in early to mid-October and peak emergence in early to mid-May (Table 1.3). During incubation, coho spawning areas received 437 temperature units ($\bar{T}$) and had a mean temperature of 1.9°C (Table 1.3). Coho fry that emerge in early July may incubate in cooler conditions or may be the offspring of fish that spawn in winter (Study 3); spawning as late as February has been observed in other areas of the Yakutat Forelands (e.g., Tawah Creek; Fig. H.4), and spawning also may occur very late in the Situk River watershed.

Chum Salmon

The migration and spawning characteristics of chum salmon in the Situk River are similar to other coastal Alaska streams (Helle 1960). Glacial moraine deposits adjacent to spawning areas probably are groundwater aquifers that supply those areas with upwelling water[15] where chums often prefer to spawn (Helle 1960; Bishop 1981).

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[13]Leon Shaul, Alaska Dep. Fish and Game, Div. Commercial Fisheries, Southeast Region (1), 802 Third St., Douglas, AK 99824. Pers. commun., Dec. 1991.

[14]Robert Johnson, Alaska Dep. Fish and Game, Div. Sport Fish, Southeast Region (1), 802 Third St., Douglas, AK 99824. Pers. commun., Nov. 1991.

[15]Steve Paustian, U.S. Forest Service, Tongass National Forest, Chatham Area, 204 Siginaka Way, Sitka, AK 99835. Pers. commun., April 1991.

Migration of adult chums into the Situk River begins in early August, peaks in late August, and ends in early September[2]. Distribution of spawning is poorly known; however, spawning in 1988 was observed in Old Situk River primarily upstream of the highway, and in the main stem from 3 km upstream of the highway to 7 km downstream of the highway (Fig. 1.12). At least one-half of the chums probably spawn within the flood zone (Fig. 1.5), and spawning probably peaks in late August. Spawning habitat in the Situk River was not measured, but general spawning habitat characteristics are summarized in Appendix 1.

Brood-year 1988 chum eggs and alevins probably incubated for about 240 days in the Situk River (Fig. 1.6); spawning peaked in late August and emergence peaked in late April (Table 1.3). During incubation, chum spawning areas received 840 temperature units ($\bar{T}$) and had a mean temperature of 3.5°C (Table 1.3).

Steelhead

The Situk River supports one of the largest runs of steelhead in Alaska (Van Hulle 1985); historical estimates exceed 20,000 fish (Knapp 1952). The river supports distinct runs of spring and fall steelhead, but most is known about the more numerous spring fish (Jones 1983; Johnson 1990, 1991; Fig. 1.3). From April through mid-June, with a peak in mid-April, spring steelhead migrate directly from the ocean to Situk River spawning areas. From August through December, with a peak in November, fall steelhead migrate from the ocean into the river, winter in the watershed, and spawn at approximately the same time as spring-run fish (Jones 1983; Johnson 1990, 1991). Spawning areas of spring and fall steelhead are moderately distinct[6], but the amount of mixing of spring and fall runs is unknown. Emigration from the river of spawned-out steelhead of both runs begins in early May, peaks in mid-June, and is complete by late July[2]. Steelhead are most numerous in the main-stem flood zone in early May (Fig. 1.4), when 60% of the escapement (3,000 fish, including emigrants) is present.

Spring steelhead spawn from late April through June (within 2-6 weeks of entering the river), and their spawning period overlaps that of fall steelhead (Johnson 1990). Many spring steelhead spawn within the flood zone (Figs. 1.5, 1.13). Surveys indicate that about 1,000 fish (one-quarter of the escapement) spawn downstream of the highway (Jones 1983). Spring steelhead also spawn in the main-stem Situk River upstream of the highway, in Old Situk River, and in the West Fork[6] (Fig. 1.13).

Most fall steelhead winter outside the flood zone. Eleven fall steelhead that were radio tagged in 1989 wintered in Situk Lake (Johnson 1991). Some fall steelhead, however, also winter in large riverine pools within the main-stem flood zone (Jones 1983), and a few may winter in Old Situk River[16]. Fall steelhead spawn mostly from late April through early June (Johnson 1990). Thus, some fall steelhead may spend 10 months in the watershed before spawning.

Nearly all fall steelhead probably spawn outside the flood zone[6] (Fig. 1.5). The most important spawning area is the first 8 km downstream of Situk Lake in the main stem (Johnson 1991). Some fall steelhead also spawn in the remainder of the main stem upstream of the highway, in Mountain Stream, in West Fork[6], and Old Situk River (Fig. 1.14). Steelhead spawning habitat in the Situk River was not measured, but general spawning habitat characteristics are summarized in Appendix 1.

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[16]Gordon Woods, Alaska Dep. Fish and Game, Div. Commercial Fisheries, P.O. Box 49, Yakutat, AK 99689. Pers. commun., Sept. 1991.

Steelhead eggs and alevins probably incubate for about 40 days in the Situk River (Fig. 1.6), based on peak spawning in late May and peak emergence in early July (Table 1.3). During incubation, steelhead spawning areas received 482 temperature units ($\bar{T}$) and had a mean temperature of 12.0°C (Table 1.3).

Dolly Varden

Seasonal distribution of Dolly Varden in the Situk River is poorly documented, but observations indicate that many adults spend much of the year in the watershed, consistent with behavior in other Alaska streams (Armstrong 1965a,b; Blackett 1968). Dolly Varden emigrate from lakes and other wintering areas (e.g., Old Situk River) in the Situk River watershed in early spring (March-April) and enter salt water; they immigrate into the watershed to feed on fish eggs and fry from April to mid-September (Fig. 1.3). Spawning probably occurs in the main stem and most tributaries (Fig. 1.15) and peaks about early October. The number of Dolly Varden in the Situk River is unknown, but, based on personal observations, at least 3,000 Dolly Varden spawn within the flood zone (Fig. 1.5). Dolly Varden spawning habitat in the Situk River was not measured, but general spawning habitat characteristics are summarized in Appendix 1.

Dolly Varden eggs and alevins probably incubate for about 235 days in the Situk River (Fig. 1.6); peak spawning probably occurs in early October, and peak emergence is in late May (Table 1.3). During incubation, Dolly Varden spawning areas received 784 temperature units ($\bar{T}$) and had a mean temperature of 2.1°C (Table 1.3).

Eulachon

Eulachon enter the Situk River in early March (Fig. 1.3), and spawning peaks in late March and is completed by mid-April. Eulachon are most numerous in the main-stem flood zone in early April (Fig. 1.4), when over 50% of the escapement is present. Nearly all eulachon spawn within the main-stem flood zone (Figs. 1.5, 1.16). Based on observations of larvae in late May, incubation is about 20 days (Fig. 1.6). During incubation, eulachon spawning areas received 49 temperature units ($\bar{T}$) and had a mean temperature of 2.6°C (Table 1.3). Spawning habitat of eulachon in the Situk River was not measured.

Table 1.1—Number of sockeye and chinook salmon tagged between 14 June and 21 August 1988, and escapement through the Situk River weir in three periods between 7 June and 22 August.

Species	Period	Number tagged	Escapement	% Tagged
Sockeye	Early	1,053	20,981	5.0
	Middle	1,642	17,907	9.2
	Late	1,850	8,118	22.8
	Total	4,545	47,006	9.7
Chinook	Early	43	280	15.4
	Middle	41	618	6.6
	Late	38	180	21.1
	Total	122	1,078	11.3

Table 1.2—Regression equations (with associated R^2 values) used in estimating the proportion ($\hat{P}$; where $\hat{P} = [\sin \hat{y}]^2$ and $\hat{y}$ is in radians) of the escapement of sockeye or chinook salmon in the main-stem flood corridor of the Situk River during each tagging period in 1988. Day (d) was 1 on 1 January and 366 on 31 December.

Species	Period	Regression equation	R^2
Sockeye	Early	$\hat{y} = 6.65 - 0.029d$	0.83
	Middle	$\hat{y} = 6.61 - 0.029d$	0.74
	Late	$\hat{y} = 10.11 - 0.043d$	0.83
Chinook	Early	$\hat{y} = 5.45 - 0.021d$	0.83
	Middle	$\hat{y} = 7.99 - 0.032d$	0.86
	Late	$\hat{y} = 13.78 - 0.053d$	0.68

Table 1.3—Incubation criteria of anadromous fish in the Situk River. *T* is temperature units or degree-days above 0°C. A dash indicates data are not available.

Species	Peak spawning observed	Peak emergence observed	Mean incubation temperature (°C)	$\bar{T}$ to 50% emergence estimated	*T* to 50% emergence typical
Sockeye	Aug 10-20	Apr 20-30	4.9	1,245	865[a]
Ocean-type[b] Sockeye	Aug 20-30	Apr 10-20	3.5	820	800[a]
Coho	Oct 5-15	May 5-15	1.9	437	460[a]
Pink	Aug 25-Sep 5	Apr 30-May 10	3.2	790	675[a]
Chinook	Aug 28-Sep 7	Apr 20-30	3.9	924	900[a]
Chum	Aug 23-Sep 2	Apr 20-30	3.5	840	645[a]
Steelhead	May 25-Jun 4	Jul 1-10	12.0	482	500[c]
Dolly Varden	Oct 2-12	May 20-Jun 10	2.1	784	—
Eulachon	Mar 20-30	Apr 10-20	2.6	49	—

[a] Murray and McPhail 1988.

[b] In the Old Situk River.

[c] Leitritz and Lewis 1980. Data for rainbow trout.

Figure 1.1—Inserting radio tag in a chinook salmon on the Situk River.

Figure 1.2—Measuring water velocity at a sockeye salmon redd in Old Situk River.

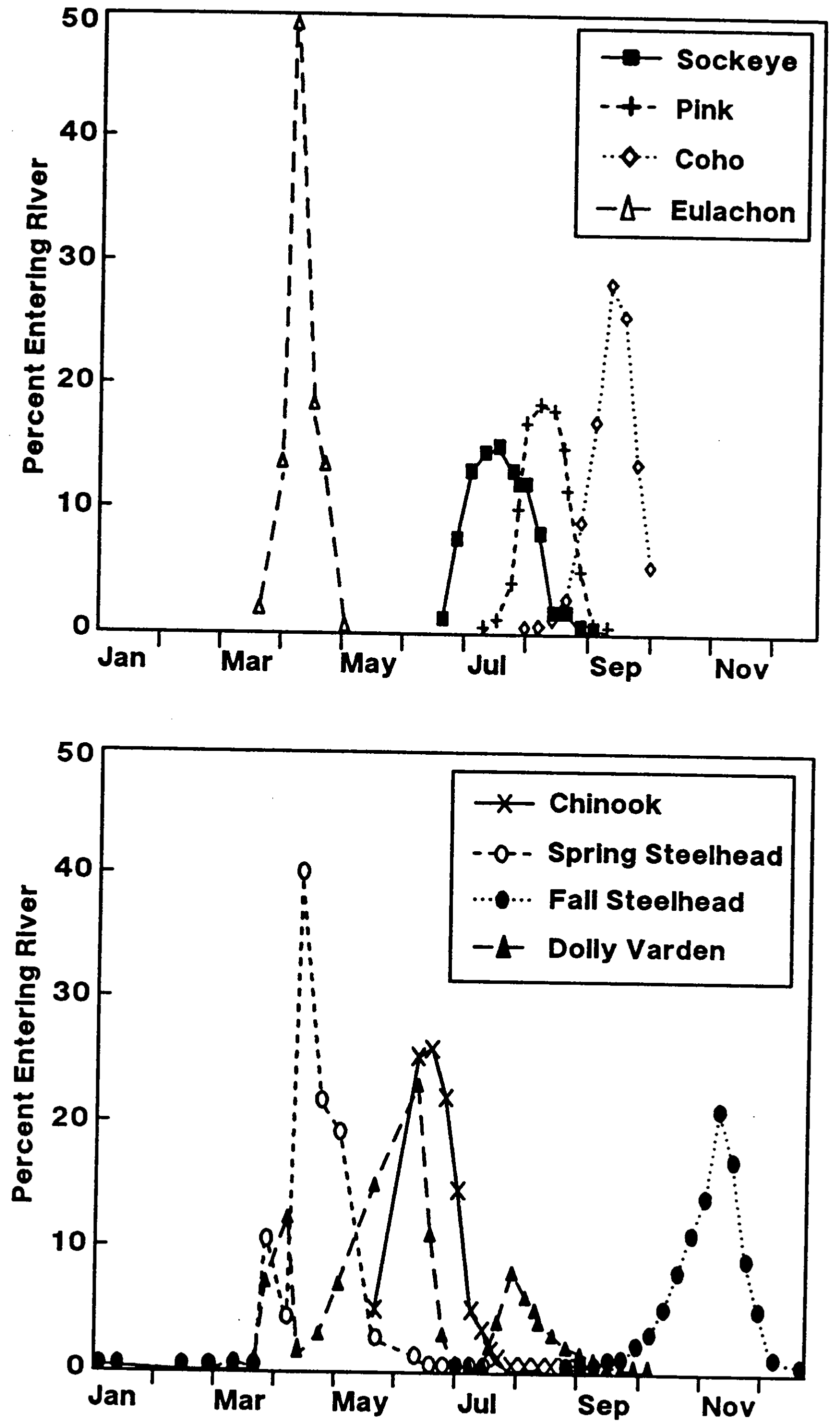

Figure 1.3—Approximate annual timing of river entry by adult anadromous fish returning to the Situk River.

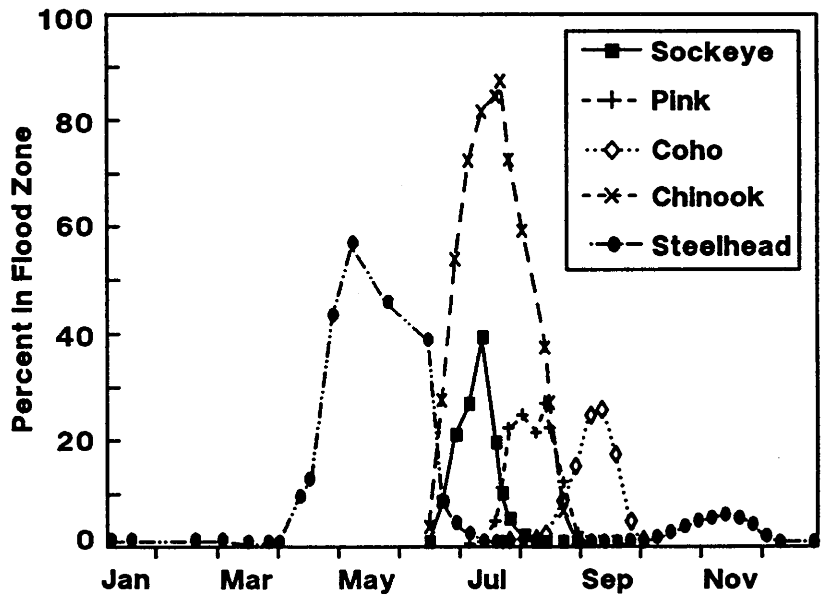

Figure 1.4—Estimates by date of the percentage of returning adult salmon and steelhead that are in the predicted flood zone.

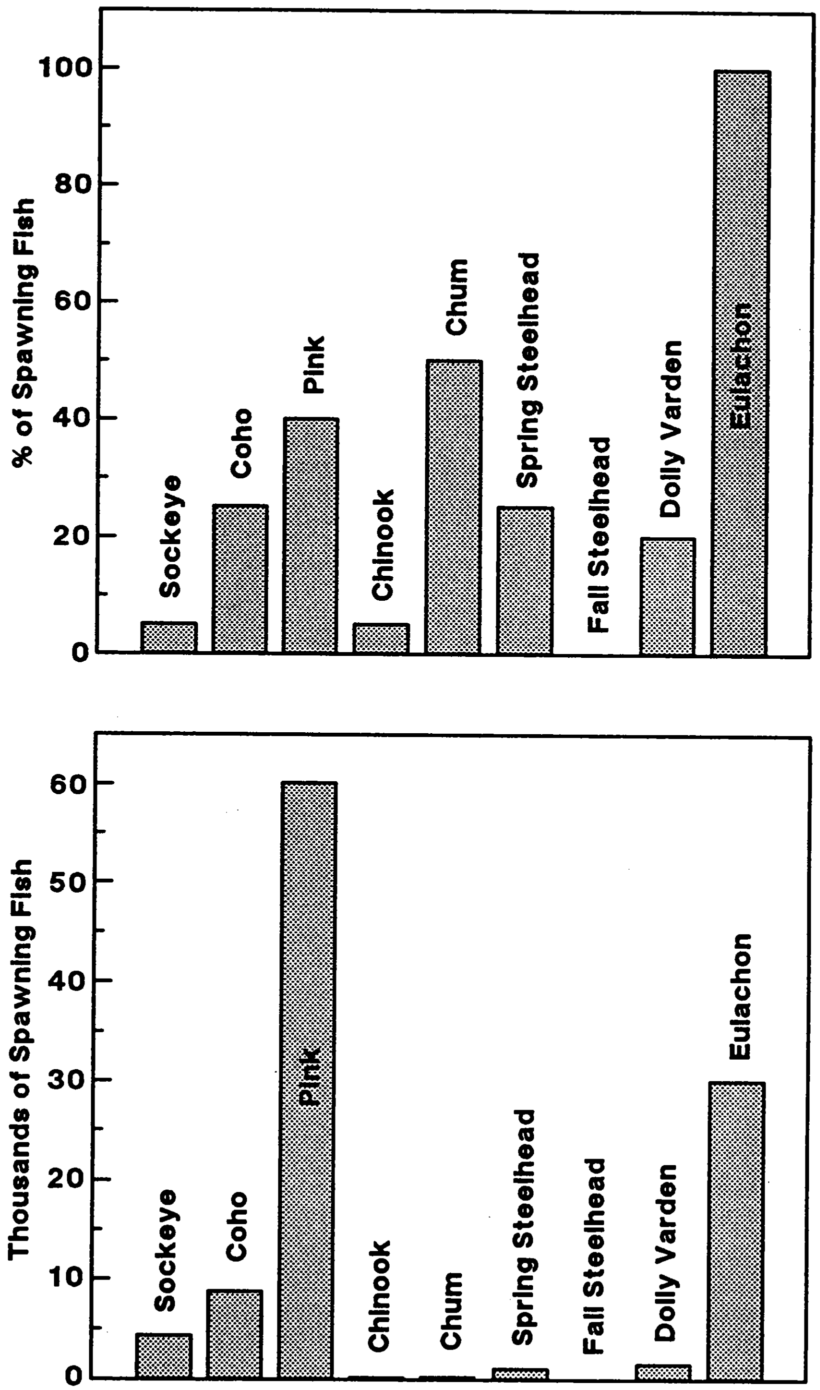

Figure 1.5—Estimates of average annual percentages and numbers of anadromous fish that spawn within the predicted flood zone of the Situk River.

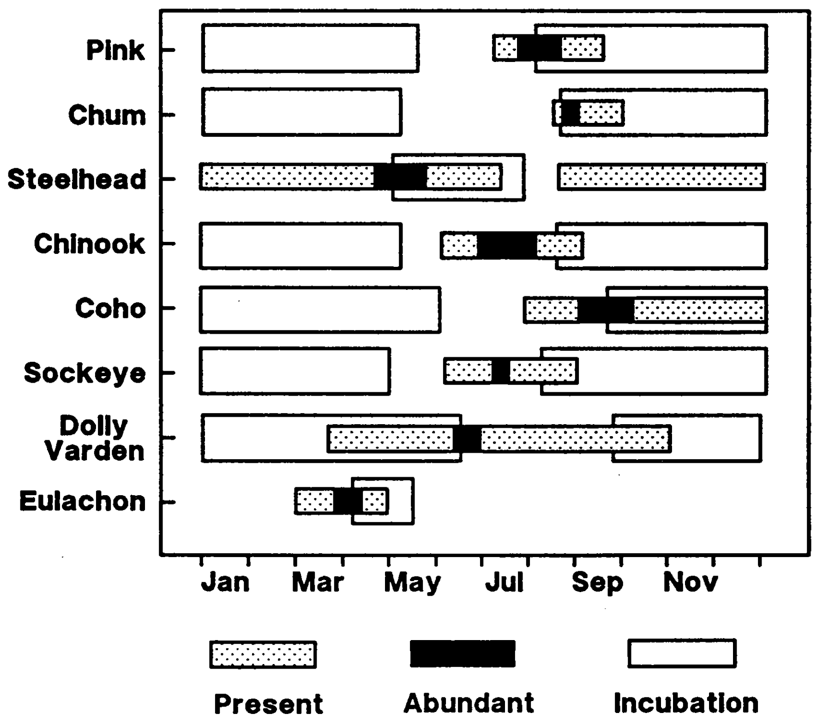

Figure 1.6—Timing and relative abundance of adult anadromous fish and egg incubation in the predicted flood zone of the Situk River.

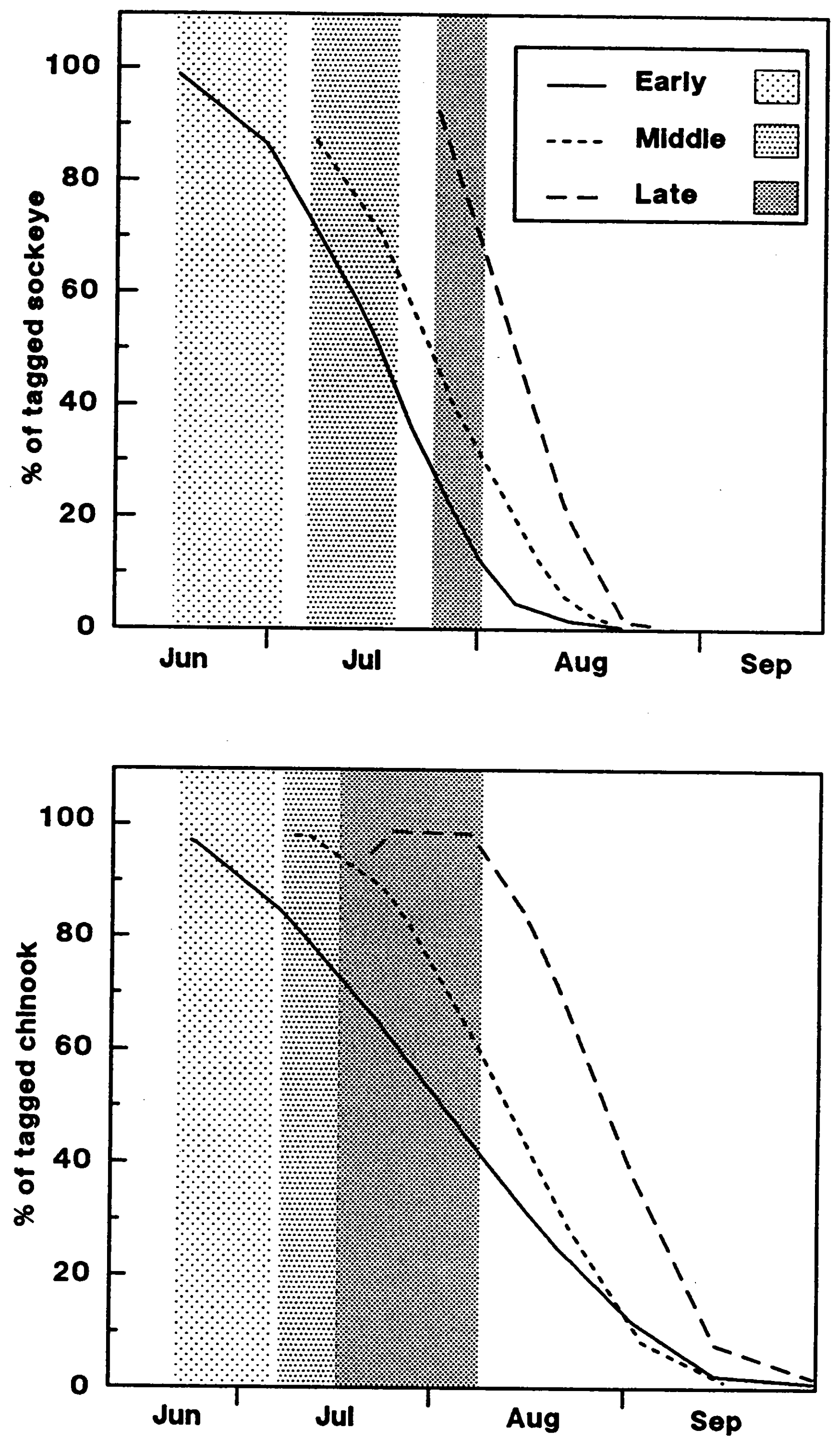

Figure 1.7—Estimated percentages of three respective groups of tagged sockeye and chinook salmon in the predicted main-stem flood zone of the Situk River, from 14 June through 14 September 1988. Shaded areas encompass tagging dates.

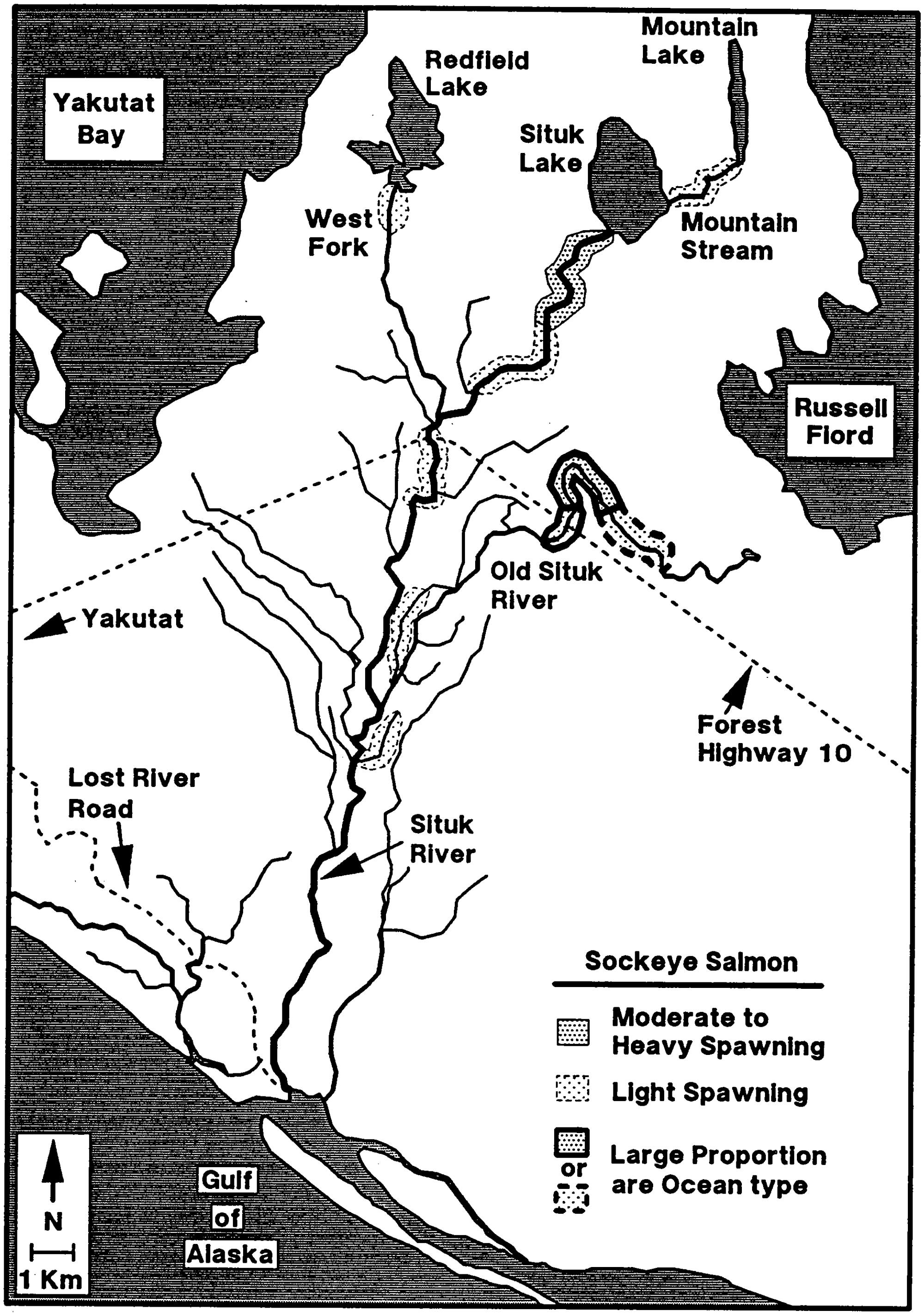

Figure 1.8—Distribution of stream spawning sockeye salmon in the Situk River watershed, 1988.

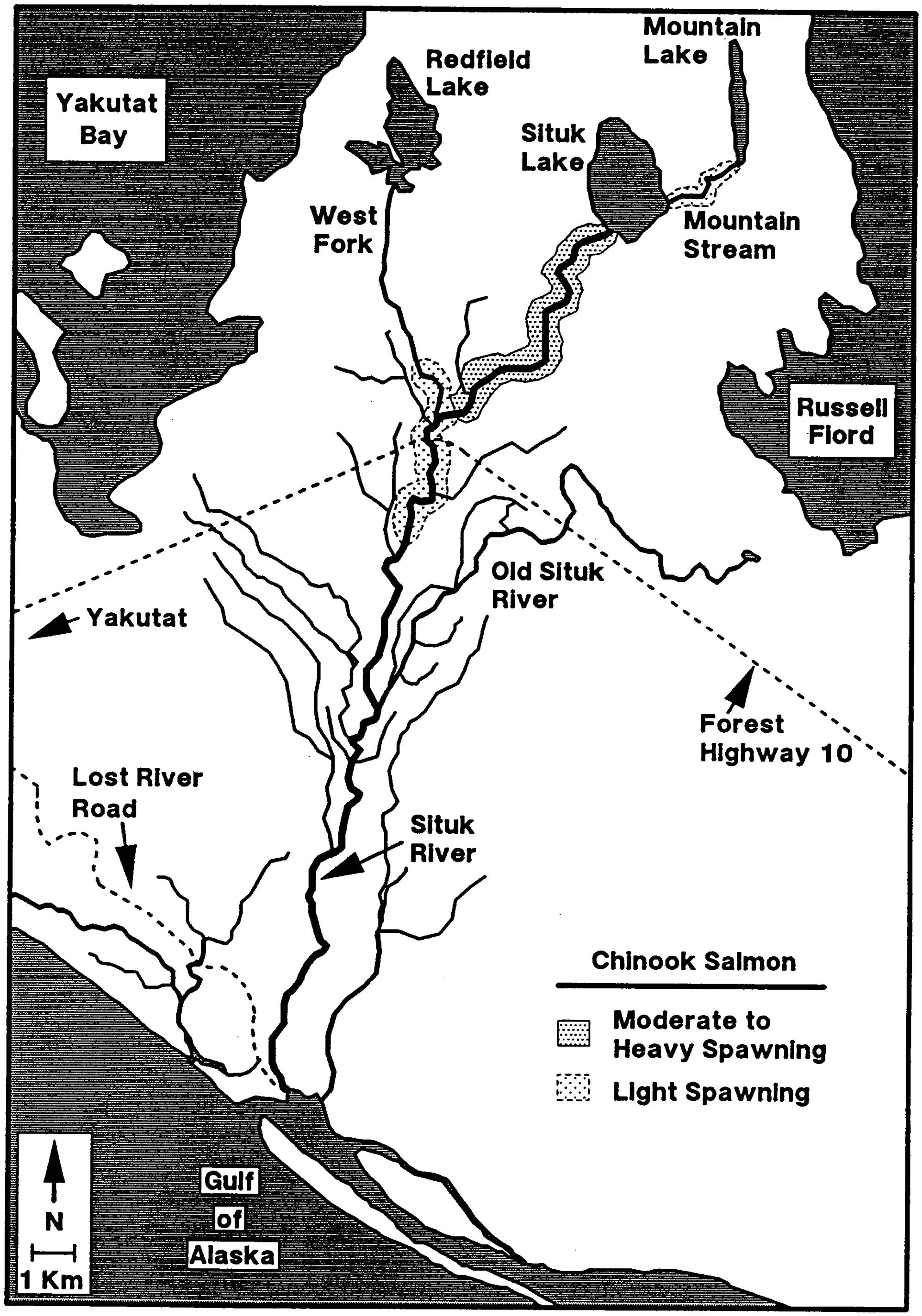

Figure 1.9—Distribution of spawning chinook salmon in the Situk River watershed, 1988.

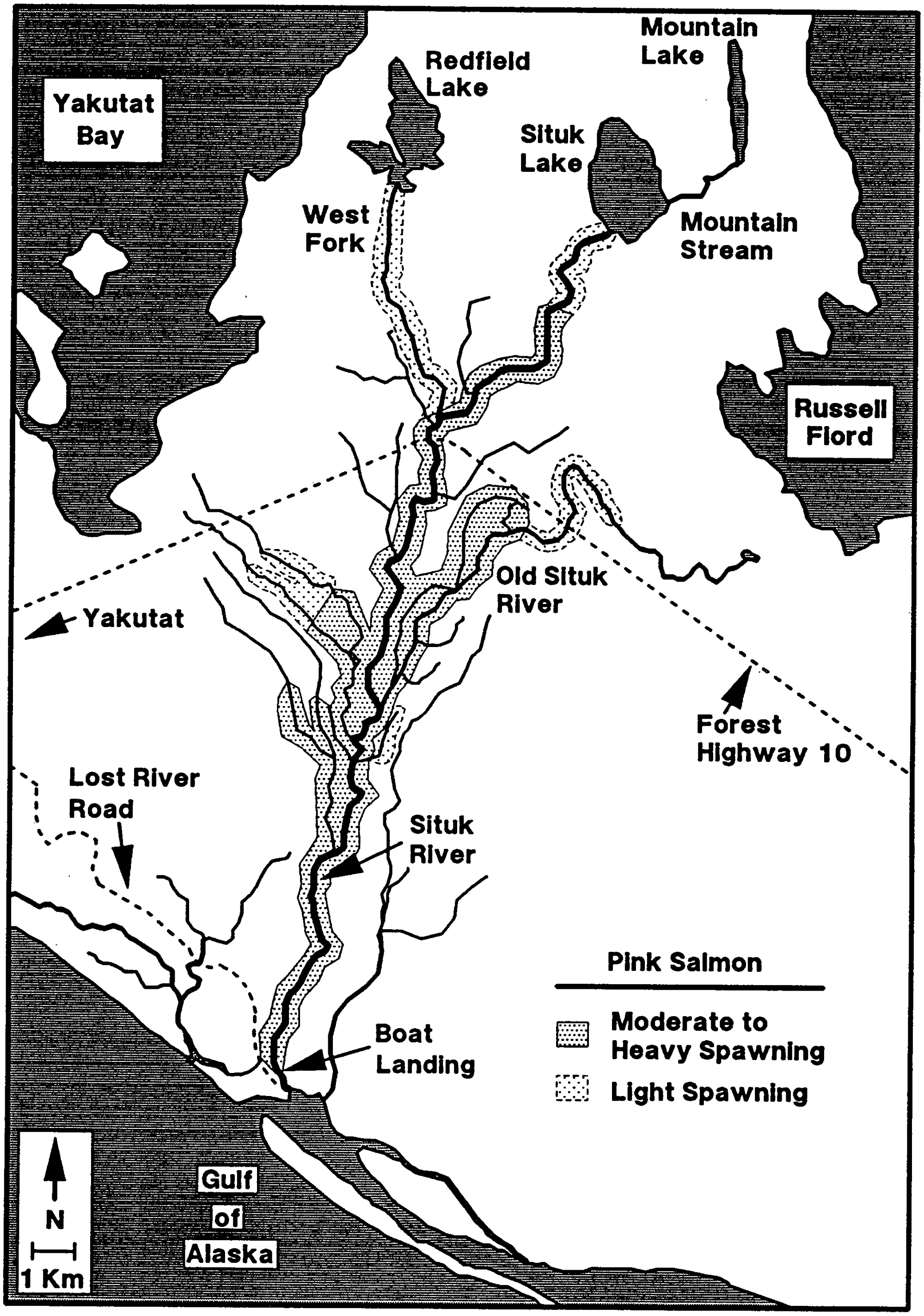

Figure 1.10—Estimated distribution of spawning pink salmon in the Situk River watershed, 1988.

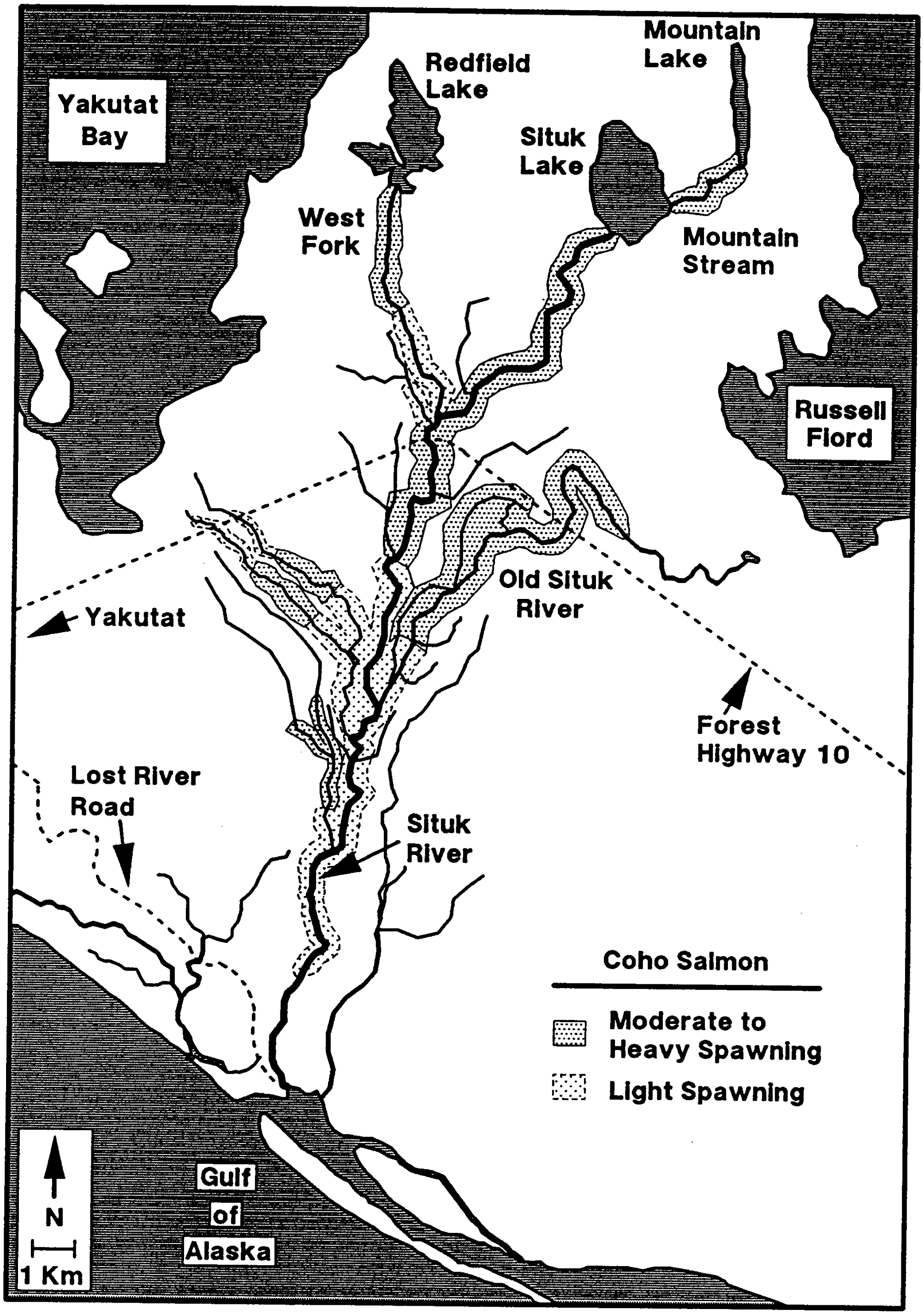

Figure 1.11—Estimated distribution of spawning coho salmon in the Situk River watershed.

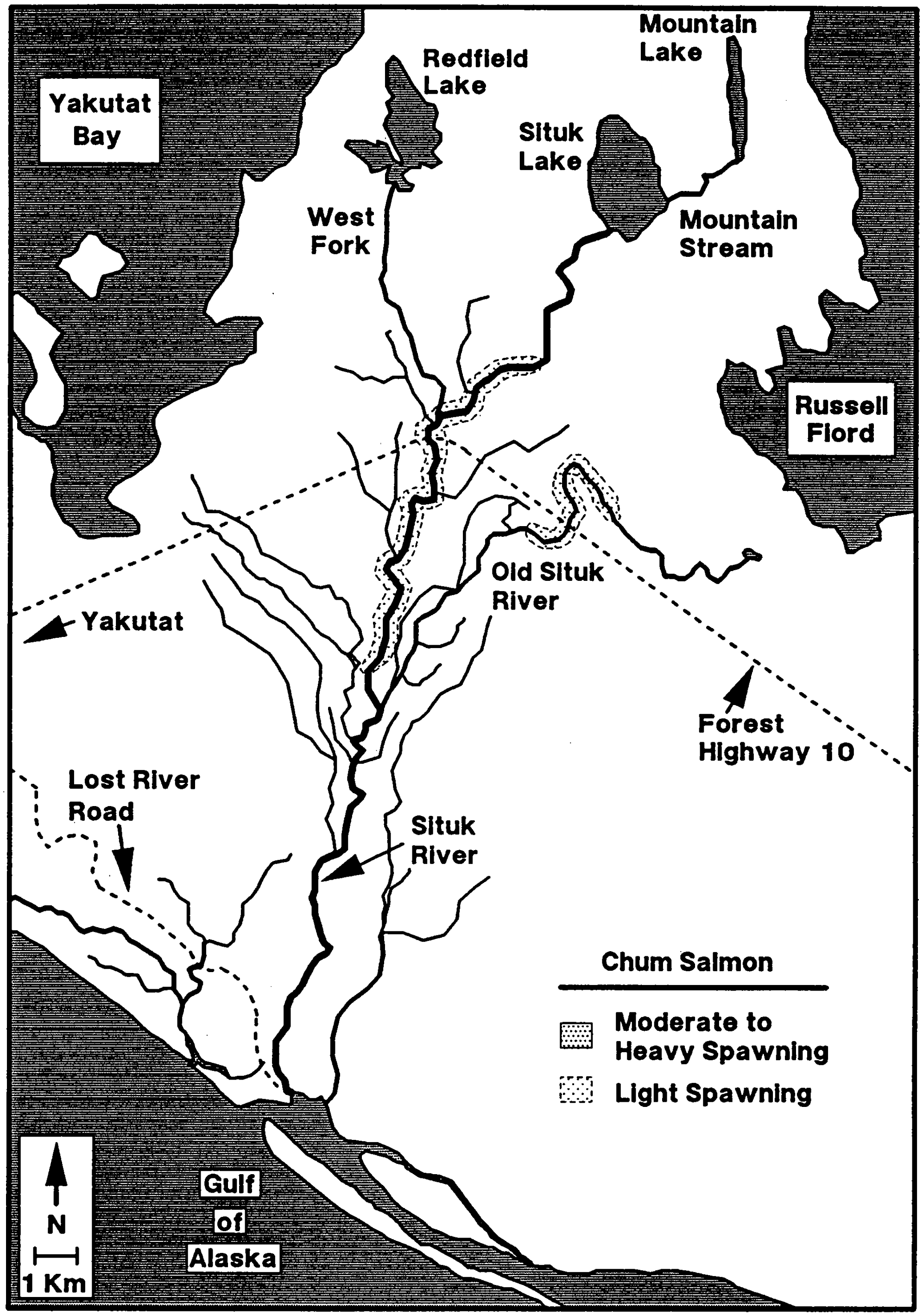

Figure 1.12—Estimated distribution of spawning chum salmon in the Situk River watershed.

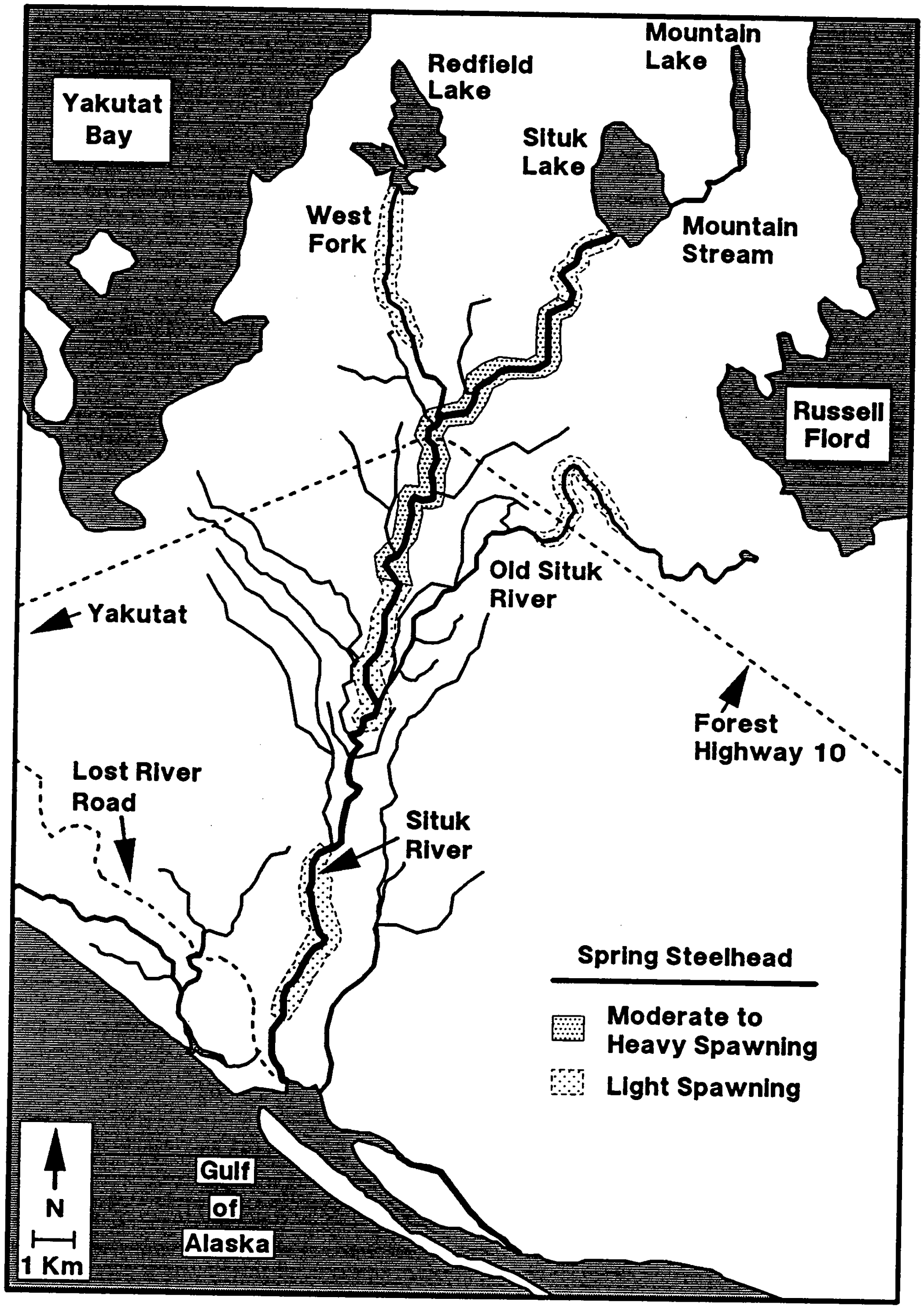

Figure 1.13—Estimated distribution of spawning spring steelhead in the Situk River watershed.

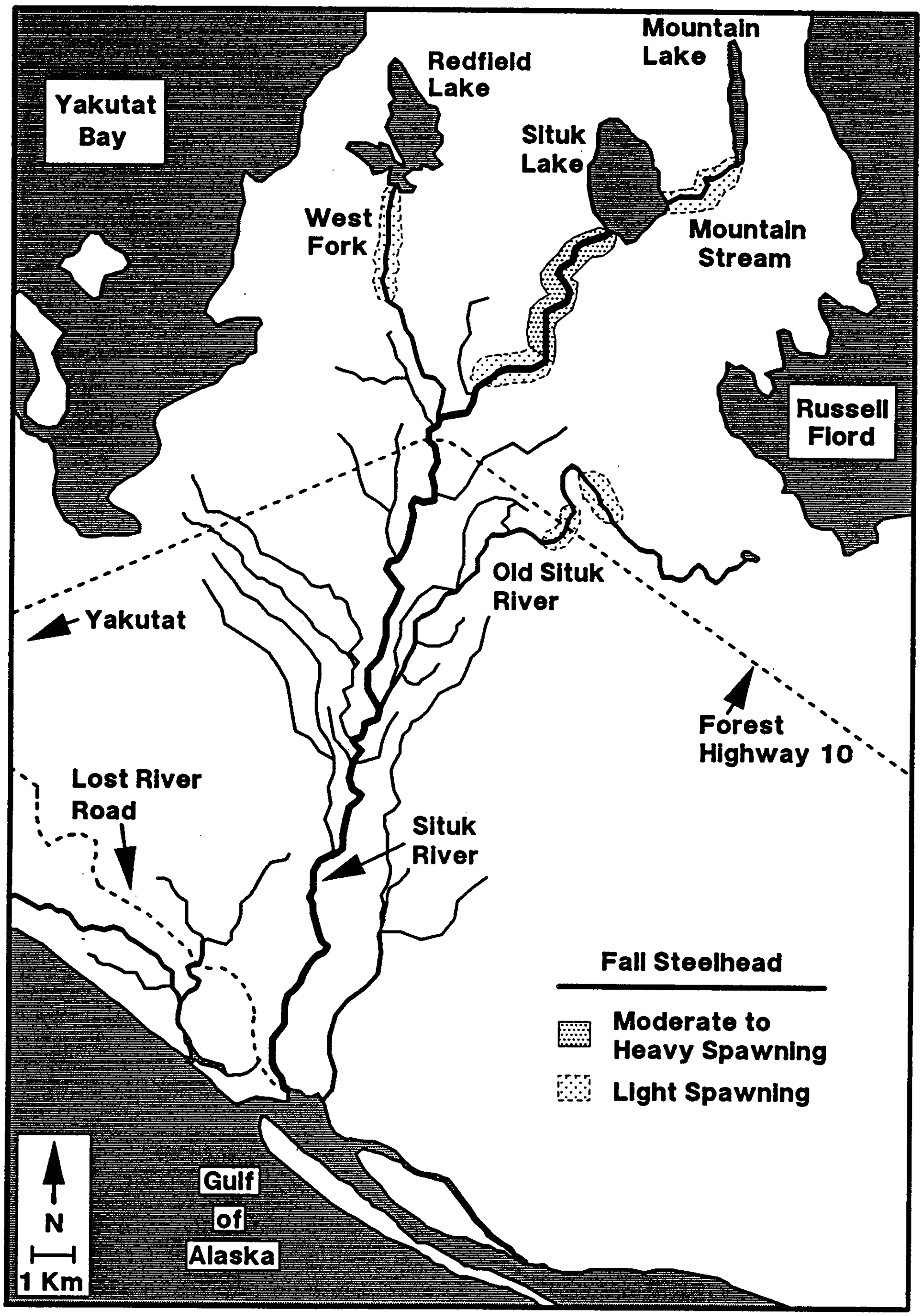

Figure 1.14—Estimated distribution of spawning fall steelhead in the Situk River watershed.

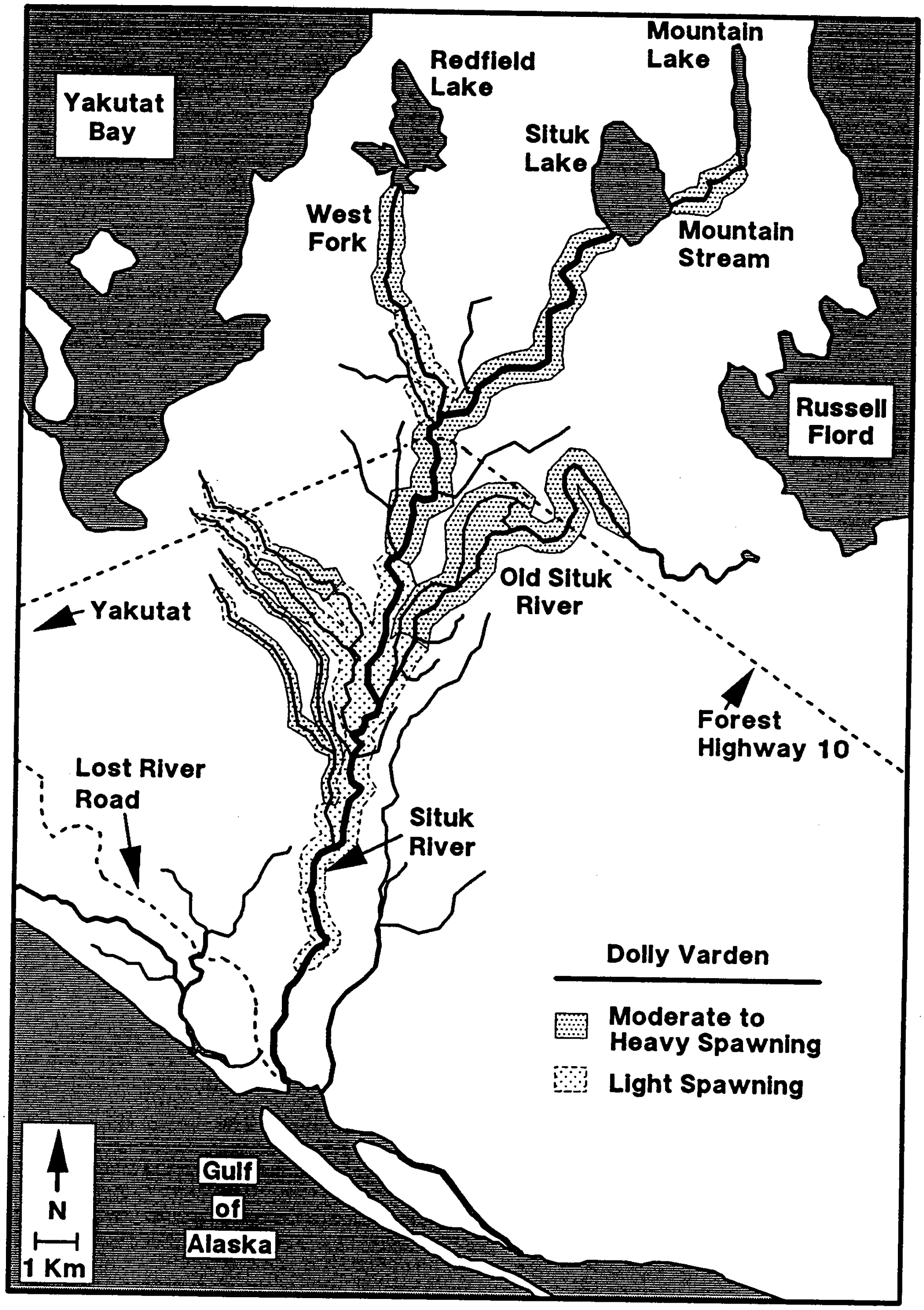

Figure 1.15—Estimated distribution of spawning Dolly Varden in the Situk River watershed.

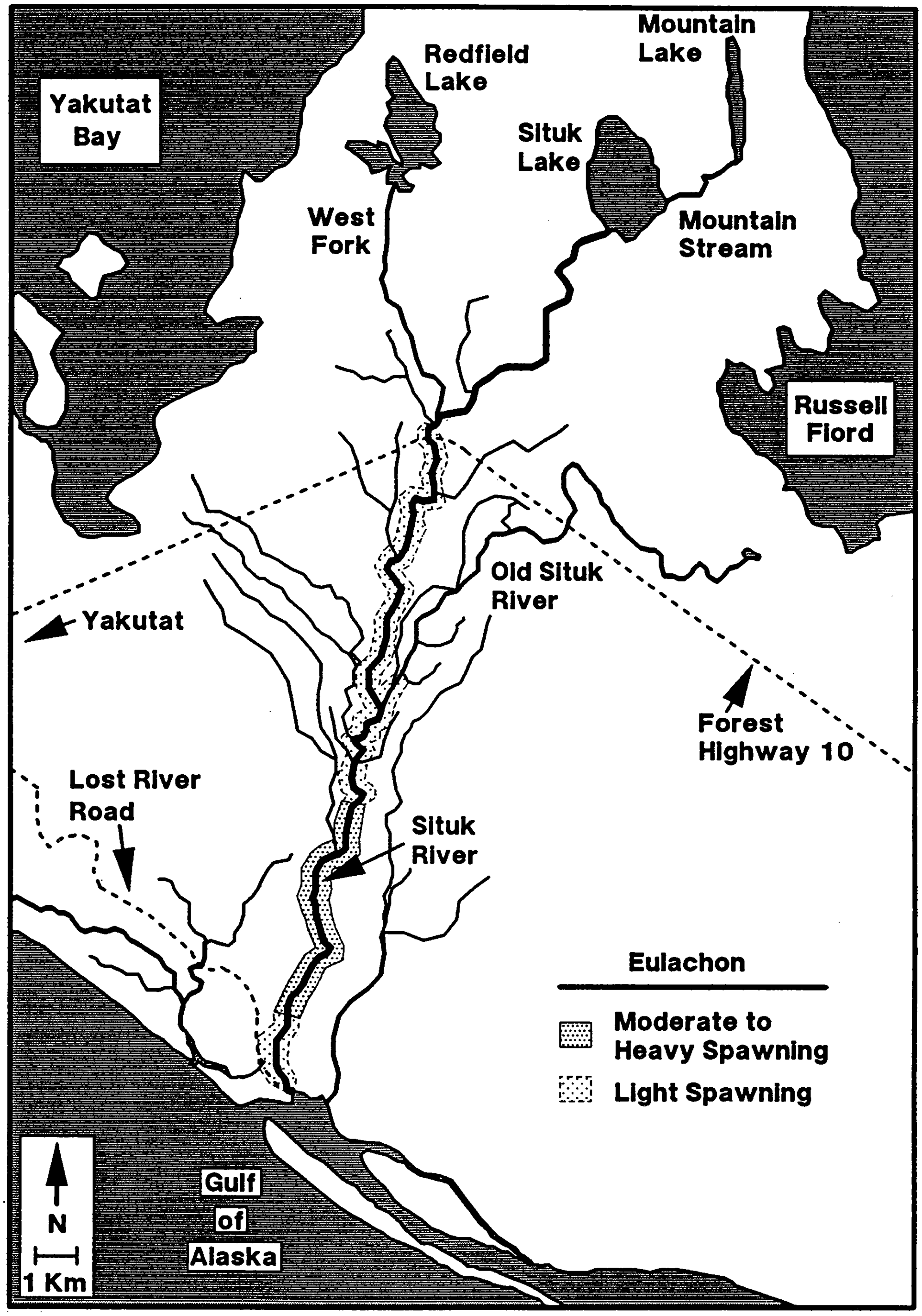

Figure 1.16—Estimated distribution of spawning eulachon in the Situk River watershed.

STUDY 2.

SUMMER DISTRIBUTION AND ABUNDANCE OF JUVENILE SALMONIDS IN THE SITUK RIVER

Rationale

Many juvenile salmonids rear in the flood zone. To determine the impacts of flooding on the salmonid stocks of the Situk River, the summer abundance and distribution of juveniles in the Situk River watershed needs to be determined.

Objectives

The objectives of this study were to determine distribution and abundance of juvenile salmonids inside and outside the flood zone of the Situk River.

Summary of Results

About 70% of the total juvenile salmonids in the Situk and Lost Rivers (excluding lakes) reared in the predicted flood zone in summers 1987-89: over 90% of sockeye, chinook, and Dolly Varden; 70% of coho; and 45% of steelhead. Coho salmon were the most abundant salmonid and were present in all study reaches, whereas chinook were present almost exclusively in the main-stem Situk River. Sockeye salmon were the least abundant and were primarily in the Old Situk River. Steelhead trout occurred in about 75% of the study reaches—40% reared in the West Fork. Dolly Varden were the second most abundant salmonid—about 90% reared in the Old Situk River.

METHODS

A stratified sampling design based on the USFS Channel Type Classification System (CTCS; Paustian 1992) was used to estimate fish populations in most areas of the Situk and Lost Rivers and partition fish populations between areas inside and outside the flood zone.

The CTCS defines "channel types" based on physical attributes, such as channel gradient, streambank incision and containment, and riparian plants. Channel types are grouped into "fluvial process groups" according to hydrologic, geomorphic, geologic, glacial, and tidal influences on fluvial erosion and deposition. Channel types are designated by a number preceded by two letters abbreviating the process group (e.g., FP3 for one type of floodplain channel). Phases of channel types are sometimes recognized, based on riparian vegetation, geomorphology, and other features, and are identified with a lower-case suffix (e.g., FP3a).

Most stream channels in the study area were of seven channel types: four floodplain channels (FP1, FP3, FP4, and FP5), two palustrian channels (PA1 and PA3), and one estuarine channel (ES4) (Fig. 2.1-2.7; Table 2.1). Two phases of the FP3, FP4, and FP5 channels were present but phases were combined for analysis. Because of the short lengths of ES4 channel, it was combined with the FP5 (river main stem) in the Situk River and with the FP1 (uplifted main-stem beach channel) in the Lost River for analysis.

Study sites were located in the Situk River, Lost River, Kunayosh Creek, and Seal Creek drainages (Fig. 2.1). A total of 47 sites were sampled but because of difficult logistics, only three sites were in Kunayosh and Seal Creeks, and these were not included in the analysis. The only riverine areas in the Situk and Lost Rivers not sampled were Mountain Stream (6 km long), and about 4 km of PA2 channel type in Tawah Creek. No lakes were sampled. Study sites in the Situk and Lost Rivers were selected to give a representative sample of habitat inside and outside the flood zone. Sites were sampled in random order to eliminate temporal bias. In each channel type we sampled five to seven reaches, each about 10 stream widths long. Each study site was sampled once during three summers from 1987 to 1989.

Habitat characteristics were measured in each study site mostly by methods described in Johnson and Heifetz (1985). Stream width, water velocity, and proportions of pools, riffles, and glides were measured for all channel types. LWD was counted and classified according to methods for verifying channel types (USFS 1990). Differences between channel types were tested with analysis of variance.

In all channel types except FP5, fish numbers were determined by the Petersen mark-recapture method (Ricker 1975). Study reaches were enclosed by blocking the upper and lower ends with seines. Fish for marking were collected with minnow traps baited with salmon roe, and after fish were removed from traps, more were collected with electroshocker and seine. This gear combination captured most fish species and sizes; however, steelhead fry were difficult to capture and their numbers were not estimated except in the channel edges of the FP5 channel type. Fish were marked by clipping a tip of the caudal fin and released. Following procedures of Peterson and Cederholm (1984), we waited 1 h before attempting recapture with electro-shocker and seine. Estimated fish number was calculated from the formula

$$\hat{N} = \frac{(M+1)(C+1)}{(R+1)}, \tag{1}$$

where $\hat{N}$ is estimated fish number, M is the number of marked fish released, C is the number of fish examined for marks in the recapture sample, and R is the number of marked fish recaptured (Ricker 1975). Fish density was estimated by dividing $\hat{N}$ by the reach area.

In FP5 channels (main-stem Situk River), because of the large size of the stream, we estimated fish populations in individual habitat types instead of the stream reaches used for habitat measurements. We sampled three principal types of habitat: channel edges without cover (Fig. 2.8), willow edges (main-channel edge with dense overhanging vegetation and submerged roots) (Fig. 2.9), and debris pools (pools containing LWD) (Fig. 2.10). Other habitat in FP5 channels was mostly main-channel thalweg little utilized by rearing salmonids.

Because habitat types could not be isolated with block nets, we used the removal method (Zippin 1958) with repeated seining and trapping to estimate fish numbers within habitat types. At each channel-edge site, three separate 20-m sections, 50 m apart, were seined with a net (5.4 m long, 1.5 m deep, 6-mm mesh, with a pole at each end) pulled against the current parallel to shore (Fig. 2.11). Three passes with the pole seine were usually made per channel edge; if no fish were captured the first pass, no further seining was done. At each willow-edge site, a single section, 21-134 m long, was sampled with baited minnow traps set 3 m apart. At each pool site, a single pool, 195-735 m^2 was sampled with baited minnow traps set 3 m apart. The first trap was set 3 m upstream of the lower boundary to minimize attracting fish from downstream. Traps were fished three to five times for 30-50 minutes each time, depending on habitat size. Boundaries of the habitats were not blocked. We assumed immigration and emigration were negligible and probability of capture was constant during sampling.

For the removal population estimates, the maximum likelihood method (Saila et al. 1988) was used to estimate fish number ($\hat{N}$) and probability of capture ($\hat{q}$). Total catch was used instead of $\hat{N}$ if $\hat{q}$ was less than 0.20. Fish density in each habitat was computed by dividing the population estimate by the area sampled. Area of channel edges sampled was 74 m^2 at each seined section. Area of willow edge sampled was calculated from the average width of overhanging vegetation (measured at 3-m transects) times length (measured from the uppermost trap to 3 m downstream of the lowermost trap). Because fish were concentrated near LWD within pools, area of pools was measured as the length and width of the part of the pool containing LWD. At each habitat, water depth was measured at one-quarter, one-half, and three-quarters the distance across each transect and water velocity was measured at the same distance across the lower, middle, and upper transect.

At each study site, a random sample of fish of each species was scaled for ageing. Numbers of the different age groups of fish were not estimated separately.

The total number of juvenile salmonids in the Situk and Lost Rivers was estimated by extrapolating mean fish densities from the study sites to the total area of each channel type. All stream channels were typed and mapped on a U.S. Geological Survey topographic map (1:63,360) by the USFS, and length of each channel type was estimated with a measuring wheel. For each channel type except FP5, total number of fish ($\hat{N}_T$) was calculated by multiplying total area of the channel type (calculated from total length of the channel type times mean width of the study reaches) times the mean fish density in the study reaches. For the FP5 channel type, $\hat{N}_T$ was calculated by multiplying mean fish density in the study habitats times the total area of channel edge, willow edge, and pool habitats. These habitats were marked on aerial photos (1:15,840) during a boat survey of 80% of the FP5 channel type, and area of each was measured on the photos with calipers. The habitat area in the unsurveyed portion was extrapolated based on the area in the survey portion. Width of the FP5 channel type was measured at five locations during the survey. Total numbers of fish inside the flood zone was calculated by multiplying each channel type's $\hat{N}_T$ by the proportion of the channel type's length that was inside the flood zone, then summing for all channel types.

Variance of $\hat{N}_T$ for each channel type was estimated by the bootstrap method (Efron and Tibshirani 1986) with 1,000 replications. Each bootstrap replication for channel types other than FP5 involved randomly drawing from the study reaches (with replacement) a number of reaches equal to actual sample size (a reach could appear in a bootstrap replication more than once or not at all). For the FP5 channel type, each bootstrap replication involved randomly drawing from the study habitats (with replacement) 12 channel edge, 6 willow edge, and 6 debris pool sites (the actual sample sizes). The random drawing of sites accounted for variance between sites. For each site drawn, bootstrap statistics (denoted by asterisks) were calculated to account for variance in population estimates within sites.

To estimate variance of Petersen population estimates, we calculated fish number from the formula

$$\hat{N}^* = \frac{(M+1)(C+1)}{(R^*+1)}, \qquad (2)$$

where $\hat{N}^*$ is the bootstrap population estimate, M is the number of marked fish released, C is the number of fish examined for marks in the recapture sample, and R^* is the bootstrap number of marked fish recaptured. R^* was resampled from the binomial ($\hat{N}$, $C/\hat{N}$). A bootstrap fish density was then calculated by dividing $\hat{N}^*$ by the area of the study reach. Average fish density in the bootstrap reaches was then multiplied by the total area of the channel type to obtain a bootstrap estimate of total fish number for the entire channel type ($\hat{N}_T$*).

To estimate variance of removal estimates in the three habitat types in the FP5 channels, we calculated bootstrap population estimates by Zippin's (1958) formula:

$$\hat{N}^* = \frac{T^*}{1-(1-\hat{q})^k} ; \tag{3}$$

$\hat{N}$* is the bootstrap population estimate, T* is bootstrap total catch in all removals, $\hat{q}$ is probability of capture, and k is the number of removals (seine passes or trap sets). T* was calculated as

$$T^* = \sum_{i=1}^{k} U_i^* , \tag{4}$$

where U^*_i is the bootstrap number of fish caught in removal i of k removals. For each habitat in the bootstrap sample, U^*_i was resampled k times from the binomial distribution (N^*_i, $\hat{q}$), where

$$N_i^* = \hat{N} - \sum_{i=1}^{k} U_{i-1}^* \tag{5}$$

and

$$U_0^* = 0 . \tag{6}$$

The bootstrap estimates $\hat{N}$* were then converted to densities by dividing by the habitat area sampled. Average density within a habitat type was multiplied by the total area of each habitat in the FP5 channel type and summed for the three habitat types to estimate $\hat{N}_T$* for the FP5 channel type.

Variance of the 1,000 bootstrap $\hat{N}_T$* for each channel type was used to estimate variance for the channel type's population estimate $\hat{N}_T$. This variance was multiplied by the proportion of the channel type's length that was inside the flood zone to obtain variance for the estimated populations rearing inside the flood zone. The variance estimates for all channel types were summed to obtain variance for total populations.

RESULTS

In summer, most fish of each species reared in one or two channel types and 70% reared in the flood zone (Tables 2.2, 2.3). Percentage of fish rearing in the flood zone was lower in the Lost River (59%) than in the Situk River watershed (72%). FP4 and PA3 channel types had the highest overall fish densities, and the FP1 channel type had the lowest density (Fig. 2.12; Appendix 2). The FP5 channel type, because of its large size, had the greatest number of fish (about 2 million, 40% of total), and the FP1 channel type had the fewest (139,000, 3% of total).

The total population estimate of coho was over twice as accurate as for the other species (Table 2.3). The total estimate of coho inside and outside the flood zone was ± 16%, whereas estimates for the other species ranged from ± 34% for steelhead to ± 46% for sockeye.

Coho salmon were present in all study reaches (Fig. 2.13) and were the most abundant salmonid, comprising 78% of the estimated population of all salmonids. Nearly 3 million coho (68% of the total coho population) reared in the flood zone (Tables 2.2, 2.3); 46% were in the FP5 channel type which makes up 54% of the stream area in the flood zone. Within each habitat type of the FP5 channel type, coho were the most abundant fish (mean, 519/100 m^2); coho density was greatest in willow edges (Table 2.4). Among all channel types, coho density was greatest in the PA3 channel type and least in the FP1 channel type (Fig. 2.12). The proportion of fry in the total coho catch was consistent between channel types, ranging from 36 to 100% and averaging about 80%.

Sockeye salmon were the least abundant salmonid (2% of the estimated population of all fish) and occurred in only about one-half the study reaches (Fig. 2.14). Of the sockeye that reared in the flood zone (88% of the total estimated sockeye population), 96% reared in PA3 and FP4 channels in Old Situk River (Table 2.3). Sockeye were the least abundant (mean, $<1/100$ m^2) fish in the FP5 channel type (Table 2.4). Most (81%) sockeye were fry.

Chinook salmon made up about 5% of the estimated total juvenile salmonid population (Table 2.3) and occurred almost exclusively in the Situk River main stem (FP5 channel type) (Fig. 2.15). Mean density of chinook in the habitat types of the FP5 channel type was 69/100 m^2 and was greatest in willow edges (Table 2.4). In other channel types, chinook were in only four reaches and their densities were low (mean, $<1/100$ m^2). About 176,000 chinook, 72% of the estimated total number in the Situk River watershed, reared in the flood zone (Tables 2.2, 2.3). No chinook were captured in the Lost River watershed. All chinook were fry.

Steelhead trout occurred in about 75% of the study reaches (Fig. 2.16) in all channel types except PA3 and made up 3% of the total estimated fish population (Table 2.3). About 40% of the total steelhead parr population was in the West Fork (FP4); density was 58 fish/100 m^2. Steelhead were present in all habitat types in the FP5 channel type but were most abundant (mean, 32/100 m^2) in willow edges (Table 2.4). A total of 45% of the estimated total steelhead population reared in the flood zone (Tables 2.2, 2.3).

Dolly Varden occurred in all but eight reaches (Fig. 2.17) and made up about 12% of the total estimated fish population (Table 2.3). Highest density was in the FP4 channel type of the Old Situk River (mean, 322/100 m^2) and was at least twelve times greater than in any other channel type (Fig. 2.12). In the FP5 channel type, Dolly Varden were most abundant in debris pools (mean, 17/100 m^2) and least abundant in channel edges (mean, $<1/100$ m^2) (Table 2.4). Of the 90% of the estimated total Dolly Varden population that reared in the flood zone (Tables 2.2, 2.3), 88% reared in Old Situk River. Age structure of Dolly Varden was not determined.

Channel types differed in habitat characteristics (Table 2.5; Appendix 3). Channel width differed significantly ($P < 0.001$; ANOVA) among channel types; FP5 channels were the widest, and PA1 channels were the narrowest. Discharge differed significantly ($P < 0.001$; ANOVA) among channel types; discharge was highest in FP5 channels and lowest in PA3 channels. LWD was most abundant (mean, 11.6 pieces/100 m^2) in FP5 channels and least abundant (means, 0.6 and 1.1 pieces/100 m^2, respectively) in PA3 and PA1 channels and differed significantly between channel types ($P < 0.07$; ANOVA). The scarcity of LWD in the PA channels was probably because of the lack of spruce or hemlock trees within their riparian zones. Percentage of pool habitat differed significantly ($P < 0.001$; ANOVA) between channel types; PA channels had the highest percentage of pools primarily because of low (<0.5%) gradient, and FP5 channels had the smallest percentage of pools. Most PA channels, because of the lack of LWD, had homogeneous habitat consisting of low velocity water with little variation in depth. Although PA channels had the lowest gradient, all channels had low gradient, usually less than 1%, reflecting the flat topography of the Yakutat Forelands. Depth differed significantly ($P > 0.07$; ANOVA) among channel types.

Most (57% of length and 69% of area) of the study area is within the flood zone (Table 2.6). The percentage of stream length of each channel that is in the flood zone ranges from 35% for the PA1 channel type to 100% for the PA3 channel type. All FP1 channel type is within the Lost River watershed, and all FP4 and FP5 channel types are within the Situk River watershed.

DISCUSSION

Estimates of the total number of juvenile salmonids rearing in the study area is plausible except for chinook. The estimated total number of chinook that reared in summer was high based on smolt production (Study 7) and average adult returns (Study 1). The high estimate was probably because more than 90% of chinook migrate from the Situk River as ocean-type fish. Most chinook rear their first 2-3 months in the upper 10 km of the Situk River and then begin a slow migration to the lower river before migrating to sea in late July and early August (Studies 4 and 7). Because of logistical difficulty in accessing the upper main-stem Situk River, sampling of the main stem was limited to the lower three-quarters of the river. When the main stem was sampled, most chinook had migrated from the upper river; therefore, estimates of chinook densities were disproportionately high, and the estimate of the total number of chinook in the main stem was skewed.

The fish population estimates had relatively wide confidence limits for all species. This is reasonable considering that study sites were sampled during a three month period in three different summers. Juvenile fish density changes annually and seasonally based on the number and success of spawning adults, the effects of protracted emergence of fry, mortality, migration, and environmental conditions. Escapement of adults to the Situk River was relatively constant during the study but egg survival is unknown. Coho fry emergence begins in April and continues for several months (Study 1). Chinook migrate from upriver rearing habitat to the lower river in summer; thus, depending on the location and time of sampling, density of chinook could vary drastically.

Because most of the population of each species reared in specific channel types, flooding will affect each species differently. Flooding will inundate the entire Old Situk River and thus, in summer, affect the rearing habitat of most Dolly Varden and riverine sockeye, whereas West Fork is upstream of the flood zone and will provide refuge for many rearing steelhead. Nearly all chinook rear in the main-stem Situk River both inside and outside the flood zone (Study 4). Coho flourish throughout the Situk and Lost River watersheds, especially in PA channels which are predominately in the flood zone.

Coho density in the Situk River was much higher than reported for other rivers in Southeast Alaska. Mean coho densities in FP3, FP4, and FP5 channel types in the Situk River ranged from 176 to 278 fish/100 m^2 but ranged from only 8 to 35 fish/100 m^2 in other streams in Southeast Alaska[11] (Table H.1). In the FP4 channel type of Porcupine Creek (Murphy et al. 1984), coho densities ranged from 27 to 76 fish/100 m^2; in a combination of six FP3 and FP4 channels throughout Southeast Alaska (Murphy et al. 1986), coho densities in streams in old-growth and logged watersheds ranged from 75 to 178 fish/100 m^2.

Dolly Varden density in the Situk River was similar to other streams in Southeast Alaska. For 37 streams in Southeast Alaska[11], mean Dolly Varden densities in FP3, FP4, and FP5 channel types were 34, 29, and 19 fish/100 m^2 compared to mean densities of 17, 170, and 1 fish/100 m^2 in the Situk River.

Most juveniles, with the exception of sockeye, rear within the study area. Most sockeye in the Situk River watershed rear in Situk, Mountain, and Redfield Lakes[12] and in the Lost River watershed rear in Summit Lake. Coho, steelhead, chinook, and Dolly Varden, however, generally prefer riverine habitat, thus, few fish of these species probably rear in the lakes. Results of this study are therefore relevant to all juveniles except lake-type sockeye.

Table 2.1—Characteristics of channel types in the Situk River and adjacent watersheds as defined by the Channel Type Classification System (adapted from Paustian 1992).

Channel type	Stream gradient (%)	Incision depth (m)	Bank-full width (m)	Bank-full depth (cm)	Dominant substrate	Riparian vegetation	Adjacent[a] landform
FP1f[b]	0.5-1	<2	12-23	60-90	Sand and fine gravel	Alder/willow, Sitka spruce/ Devils club	Glacial outwash floodplain Forested
FP1s[c]	<0.5	<2	11-22	100-160	Sand and fine gravel	Alder/willow, willow/sedge	Beach and dune landforms Non-forested
FP3f	1	1	4-7	30-40	Sand and fine gravel	Sitka spruce/devil's club Sitka spruce/*Vaccinium*/devil's club	Forested flat lowland Floodplain
FP3s	1	1	4-7	30-40	Sand and fine gravel	Alder/salmonberry Alder/willow	Non-forested flat lowland Floodplain
FP4f	0.5-1.5	0.3-2	12-23	60-90	Gravel and cobble	Sitka spruce/cottonwood/willow Sitka spruce/devil's club/*Vaccinium*	Glacial outwash floodplain Forested
FP4s	<0.5	0.3-2	12-23	60-90	Sand and gravel	Willow/sedge, alder/willow, and cottonwood/alder	Glacial outwash floodplain Non-forested
FP5f	0.5-1	<2	21-34	60-90	Gravel	Sitka spruce/cottonwood/alder/ devil's club, cottonwood/alder	Glacial outwash floodplain Forested
FP5s	0.5-1	<2	21-34	60-90	Sand and gravel	Alder/willow/salmonberry *Myrica gale*/willow	Glacial outwash floodplain Non-forested
PA1	<0.5	<1	3-4.5	40-70	Silt, sand, fine organics	*Equisetum*/sedge, willow/sedge *Myrica gale*/willow	Glacial outwash plain Non-forested
PA3	<0.5	<1	7-14	60-80	Organics, sand, and silt	*Equisetum*/sedge, willow/sedge Willow/alder, Sitka spruce, Cottonwood	Braided glacial outwash plain, cut-off slough

[a]Glacial outwash floodplain refers to channels created by past glaciers.

[b]Foreland outwash forested phase.

[c]Foreland outwash shrub phase.

Table 2.2—Percentage of juveniles that rear inside and outside the predicted flood zone of the Situk and Lost Rivers in summer. Values do not include Situk, Mountain, and Redfield Lakes and Mountain stream in the Situk River watershed, and Tawah Creek watershed upstream of the predicted flood zone in the Lost River watershed.

	Coho	Sockeye	Chinook	Steelhead	Dolly Varden
			Situk River		
% Inside	69	89	72	37	92
% Outside	31	11	28	63	8
			Lost River		
% Inside	59	55	0	58	52
% Outside	41	45	0	42	48
			Situk and Lost Rivers		
% Inside	68	88	72	45	90
% Outside	32	12	28	55	10

Table 2.3—Comparison of estimated number of juvenile salmonids by channel type rearing inside and outside the flood zone of the Situk and Lost Rivers in summer (80% confidence intervals are in parentheses).

	Inside flood zone		Outside flood zone		Total	
	$\hat{N}$	80% CI	$\hat{N}$	80% CI	$\hat{N}$	80% CI
			Coho			
FP1	104,355	(82,262-126,448)	30,071	(18,211-41,931)	134,426	(109,351-159,501)
FP3	235,707	(175,867-295,547)	169,762	(118,978-220,546)	405,469	(326,985-483,953)
FP4	268,502	(107,403-429,601)	300,113	(129,794-470,432)	568,615	(334,177-803,053)
FP5	1,293,468	(927,233-1,659,704)	503,016	(274,627-731,404)	1,796,484	(1,364,871-2,228,097)
PA1	176,211	(47,255-305,167)	324,579	(149,561-499,597)	500,790	(283,394-718,186)
PA3	707,733	(322,678-1,092,788)	0	(0-0)	707,733	(322,678-1,092,788)
TOTAL	2,785,976	(2,212,350-3,359,603)	1,327,541	(989,132-1,665,949)	4,113,517	(3,447,508-4,779,526)
			Sockeye			
FP1	509	(120-898)	147	(0-356)	656	(214-1,098)
FP3	466	(0-1,062)	143	(0-473)	609	(0-1,290)
FP4	34,159	(14,860-53,458)	8,291	(0-17,799)	42,450	(20,936-63,964)
FP5	530	(157-903)	206	(0-439)	736	(297-1,175)
PA1	1,508	(0-3,558)	2,907	(61-5,753)	4,415	(908-7,922)
PA3	48,071	(9,726-86,416)	0	(0-0)	48,071	(9,726-86,416)
TOTAL	85,243	(42,258-128,227)	11,694	(1,759-21,629)	96,937	(52,819-141,055)
			Chinook			
FP1	0	(0-0)	0	(0-0)	0	(0-0)
FP3	174	(63-285)	11	(0-39)	185	(71-299)
FP4	16	(0-119)	77	(0-304)	93	(0-342)
FP5	176,263	(101,867-250,659)	68,547	(22,153-114,941)	244,810	(157,133-332,487)
PA1	268	(0-1,057)	498	(0-1,574)	766	(0-2,100)
PA3	0	(0-0)	0	(0-0)	0	(0-0)
TOTAL	176,721	(102,321-251,122)	69,133	(22,726-115,540)	245,854	(158,167-333,541)
			Steelhead			
FP1	2,969	(0-5,955)	857	(0-2,461)	3,826	(436-7,216)
FP3	5,056	(0-13,617)	4,550	(0-12,672)	9,606	(0-21,407)
FP4	10,168	(0-28,113)	44,711	(7,082-82,340)	54,879	(13,190-96,568)
FP5	38,596	(27,720-49,473)	15,010	(8,227-21,793)	53,606	(40,788-66,424)
PA1	5,642	(0-12,356)	10,392	(1,281-19,503)	16,034	(4,716-27,352)
PA3	0	(0-0)	0	(0-0)	0	(0-0)
TOTAL	62,431	(38,607-86,256)	75,520	(35,351-115,689)	137,951	(91,248-184,654)
			Dolly Varden			
FP1	34	(0-97)	10	(0-44)	44	(0-115)
FP3	15,304	(0-37,905)	15,515	(0-38,272)	30,819	(0-62,892)
FP4	511,584	(238,658-784,510)	14,025	(0-59,215)	525,609	(248,967-802,251)
FP5	17,034	(11,247-22,822)	6,625	(3,015-10,234)	23,659	(16,838-30,480)
PA1	17,304	(0-38,279)	31,874	(3,406-60,342)	49,178	(13,817-84,539)
PA3	24,562	(4,819-44,305)	0	(0-0)	24,562	(4,819-44,305)
TOTAL	585,822	(310,391-861,254)	68,049	(9,882-126,216)	653,871	(372,364-935,378)

Table 2.4—Mean density (no./100 m²) of salmonids in three habitat types of the FP5 channel type in the Situk River. Standard error is in parentheses.

	Channel edge	Willow edge	Debris pool
Coho	161 (424)	986 (559)	766 (789)
Sockeye	1 (2)	<1 (<1)	<1 (<1)
Chinook	<1 (<1)	134 (124)	114 (158)
Steelhead	<1 (<1)	32 (19)	24 (13)
Dolly Varden	<1 (<1)	10 (9)	17 (26)

Table 2.5—Mean physical characteristics of channel types and habitat types in the FP5 channel type in the Situk and Lost Rivers, 1987-89. Ranges are in parentheses.

	FP1	FP3	FP4	FP5	FP5			PA1	PA3
					Debris pool	Willow edge	Channel edge		
No. Sites	5	7	6	4	6	6	12	7	5
Discharge (m^3/s)	0.59 (0.46-0.72)	0.15 (0.01-0.60)	0.56 (0.29-1.69)	2.8 (1.9-5.7)	1.47 (0.14-5.41)	1.44 (0.16-6.02)	0.11 (0.08-0.14)	0.06 (0.01-0.33)	0.04 (0.01-0.15)
% Pool	34.1 (0.0-61.9)	50.3 (31.2-95.2)	50.2 (25.4-66.6)	13.9 (7.4-25.9)	100 (100.0-100.0)	33.3 (0.0-100.0)	20.8 (0.0-33.3)	79.8 (8.1-100.0)	98.7 (96.3-100.0)
Average width (m)	10.14 (5.3-14.6)	5.43 (2.4-8.6)	14.6 (7.4-22.4)	28.3 (22.8-32.5)	6.7 (4.8-9.8)	4.0 (3.1-5.9)	3.7 (3.7-3.7)	2.6 (1.3-4.2)	9.4 (3.6-15.2)
Average depth (cm)	45.1 (28.5-59.2)	25.3 (9.2-48.2)	29.4 (17.9-41.0)	35.6 (30.7-47.2)	92.6 (46.0-153.0)	97.2 (62.0-125.8)	29.8 (26.3-35.7)	30.6 (14.2-49.7)	30.1 (11.3-61.8)
LWD* (No./100 m)	4.3 (0.0-18.8)	9.1 (0.0-26.8)	7.5 (0.0-28.7)	11.6 (2.5-30.9)	65.8 (20.0-142.7)	0.12 (0.0-0.7)	2.5 (0.0-5.0)	1.1 (0.0-3.9)	0.6 (0.0-2.7)

*Large woody debris >1 m long and >10 cm diameter.

Table 2.6—Length and area of each channel type inside and outside the predicted flood zone of the Situk and Lost River watersheds. Values do not include Situk, Mountain, and Redfield Lakes and Mountain Stream in the Situk River watershed, and the Tawah Creek watershed upstream of the predicted flood zone in the Lost River watershed.

Channel type	Inside flood zone Length (m)	Inside flood zone Area (m^2)	Outside flood zone Length (m)	Outside flood zone Area (m^2)
		Situk River		
FP3	12,878	70,854	12,229	55,583
FP4	8,528[a]	158,877	7,401[b]	77,488
FP5	24,336	689,682	9,654	273,594
PA1	4,830	12,558	23,667	61,534
PA3	18,664	175,442	0	0
		Lost River		
FP1	8,367	84,841	2,415	24,488
FP3	7,244	39,879	3,620	19,958
PA1	19,549	50,827	21,239	55,221

[a]Old Situk River.

[b]West Fork.

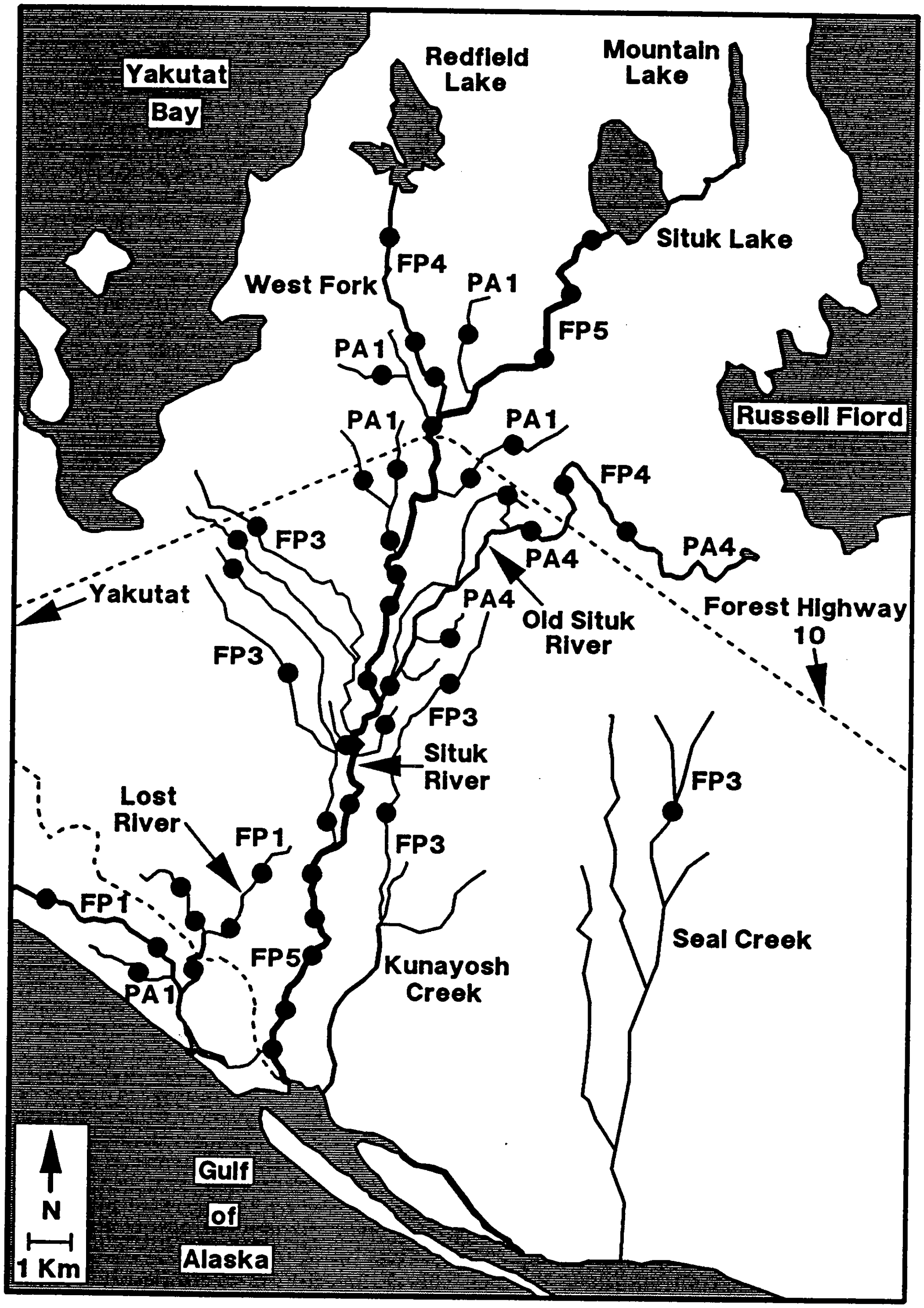

Figure 2.1—Location of study sites (solid circle) and channel types (two capital letters followed by a number) on Situk River and adjacent watersheds.

Figure 2.2—FP1 channel type on the Lost River.

Figure 2.3—FP3 channel type in the Situk River watershed.

Figure 2.4—FP4 channel type in the Situk River watershed.

Figure 2.5—FP5 channel type in the main-stem Situk River.

Figure 2.6—PA1 channel type in the Situk River watershed.

Figure 2.7—PA3 channel type in Old Situk River.

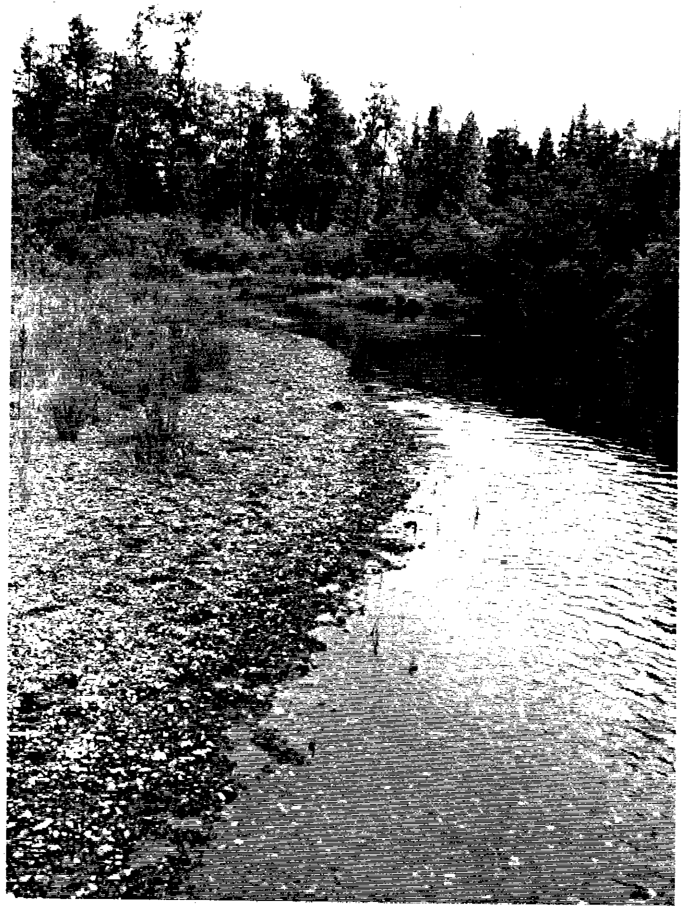

Figure 2.8—Channel edge habitat on the main-stem Situk River.

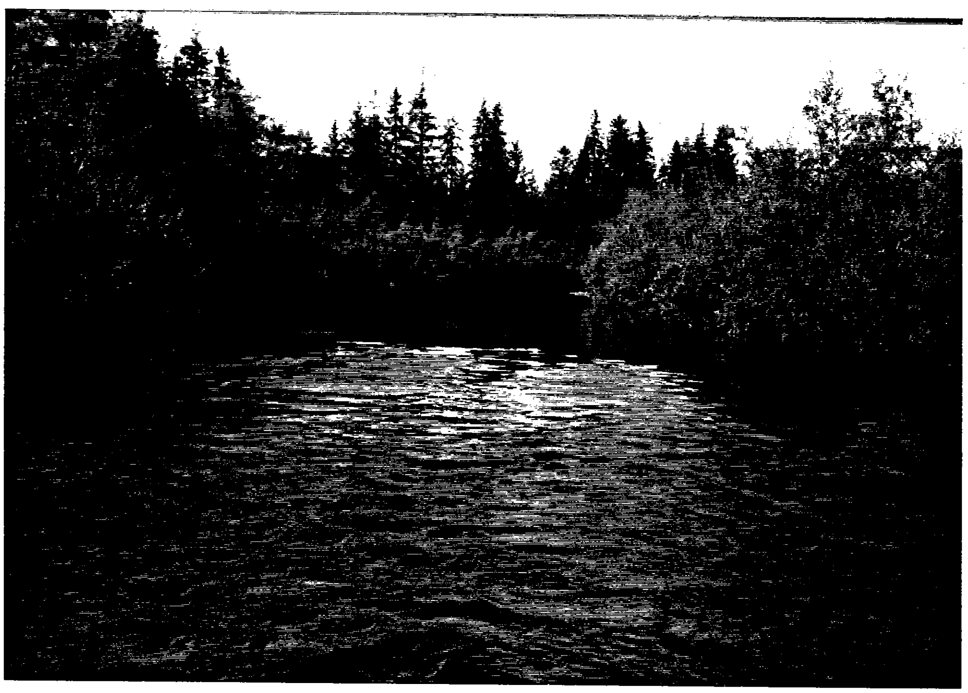

Figure 2.9—Willow edge habitat on the main-stem Situk River.

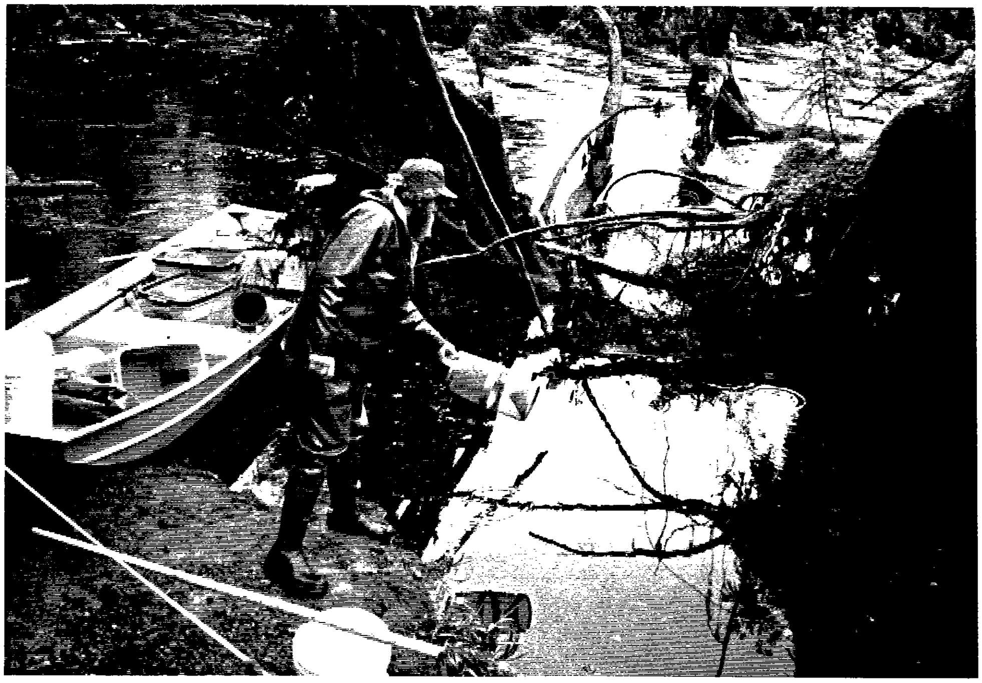

Figure 2.10—Debris pool habitat on the main-stem Situk River.

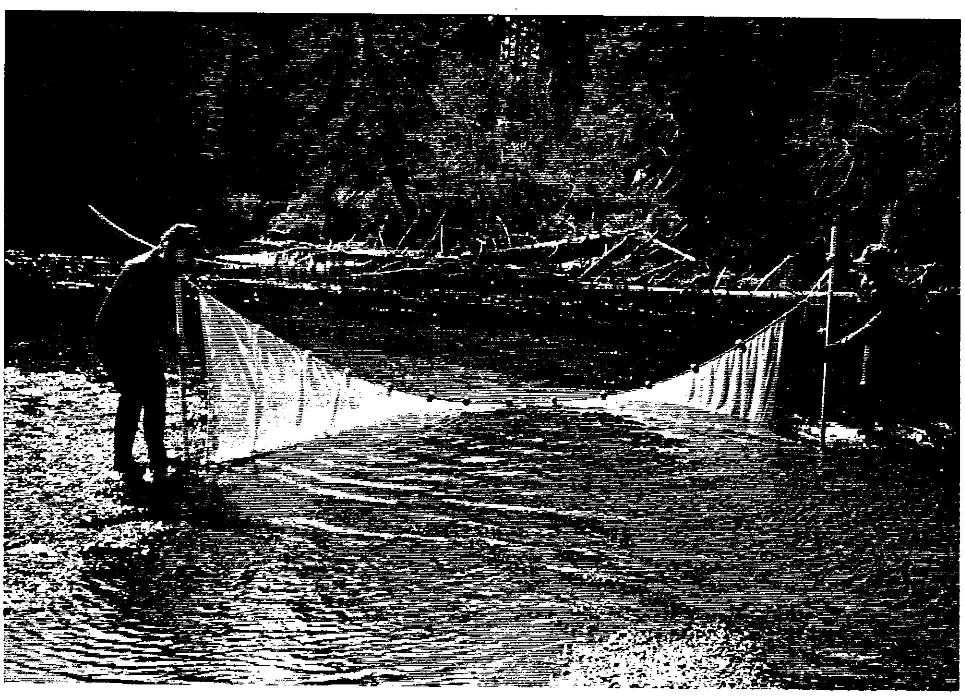

Figure 2.11—Sampling a channel edge with a pole seine on the main-stem Situk River.

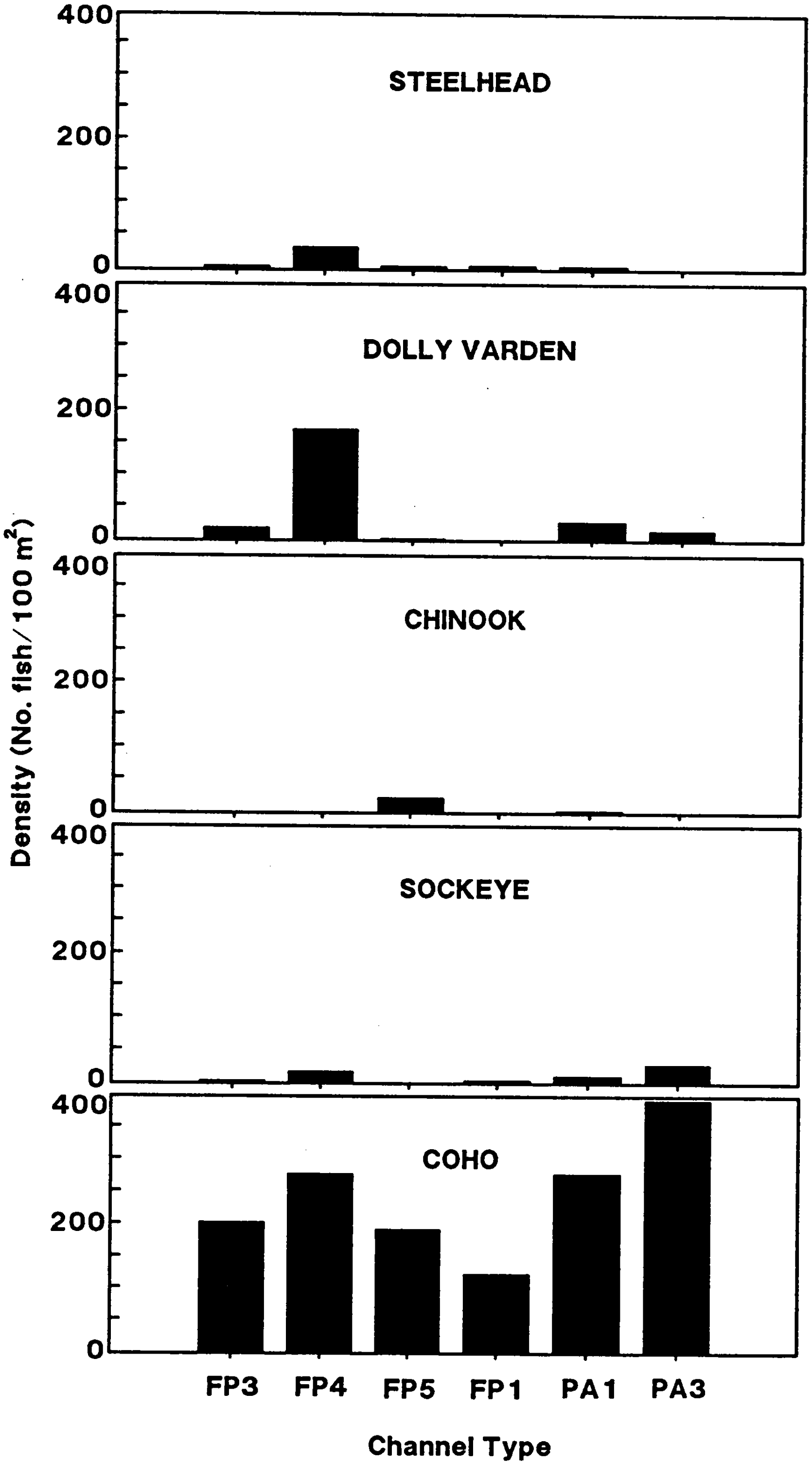

Figure 2.12—Mean density (no./100 m^2) of juvenile salmonids in summer by channel type in the Situk River and Lost River.

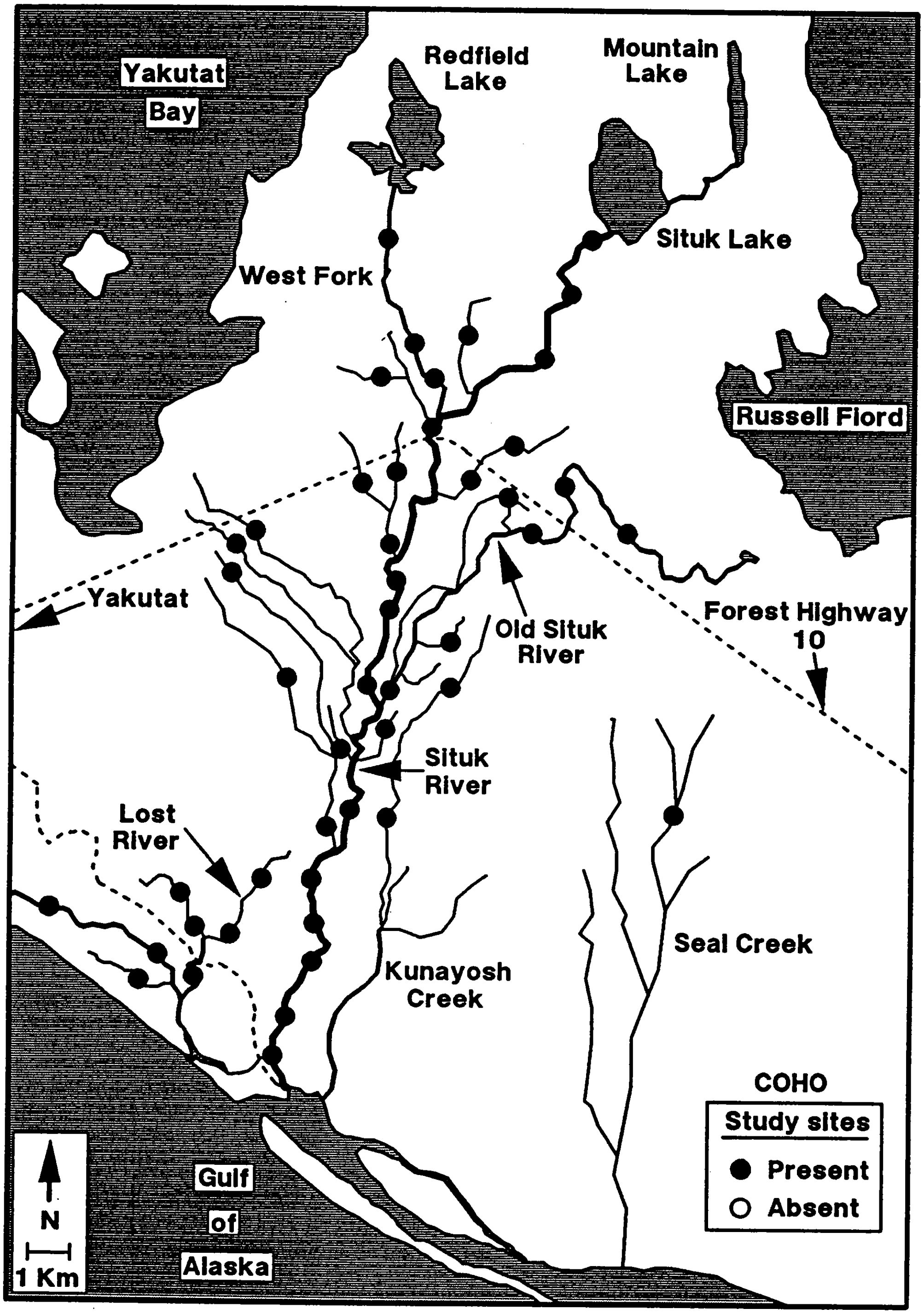

Figure 2.13—Location of study sites where juvenile coho salmon were captured.

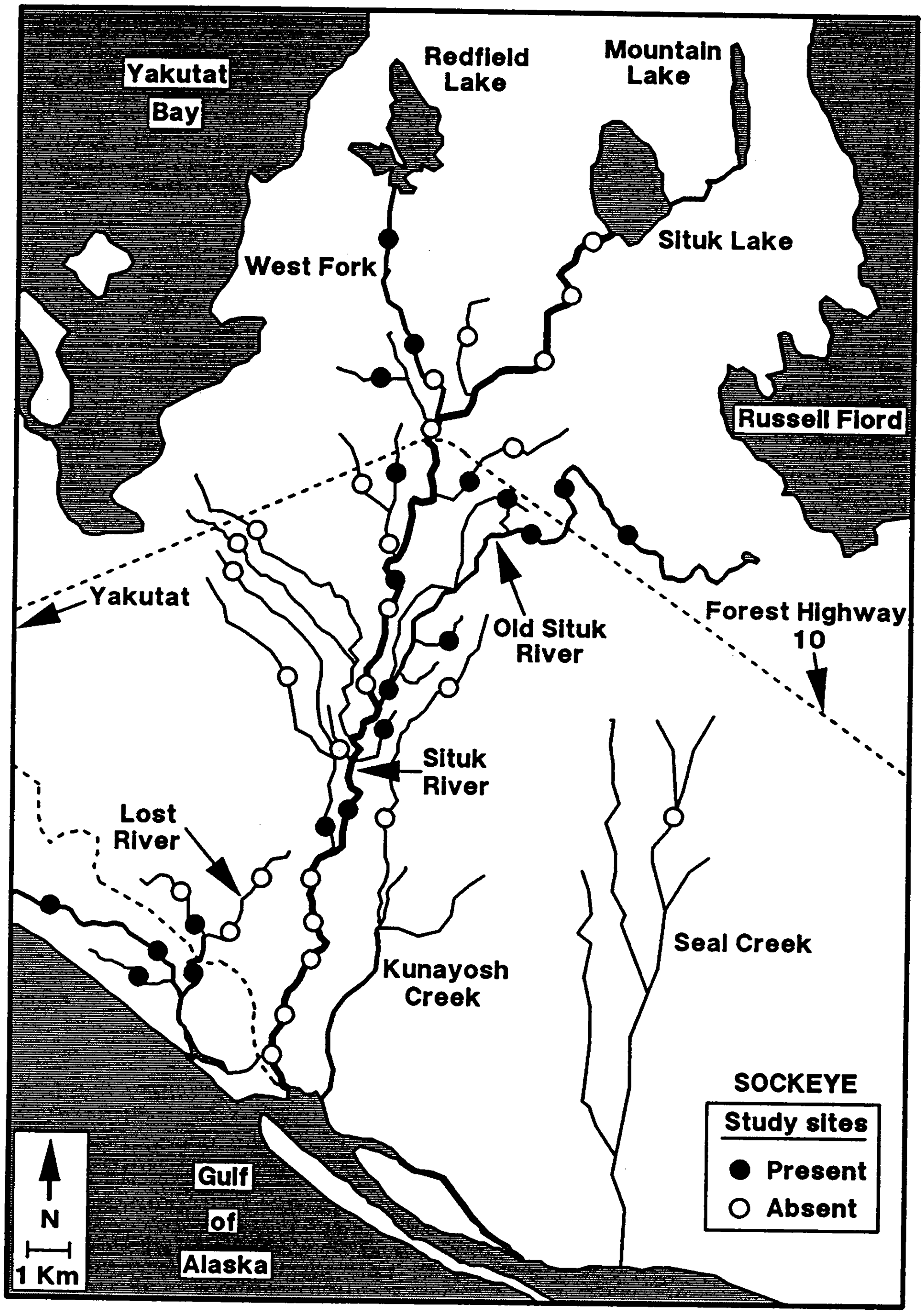

Figure 2.14—Location of study sites where juvenile sockeye salmon were captured.

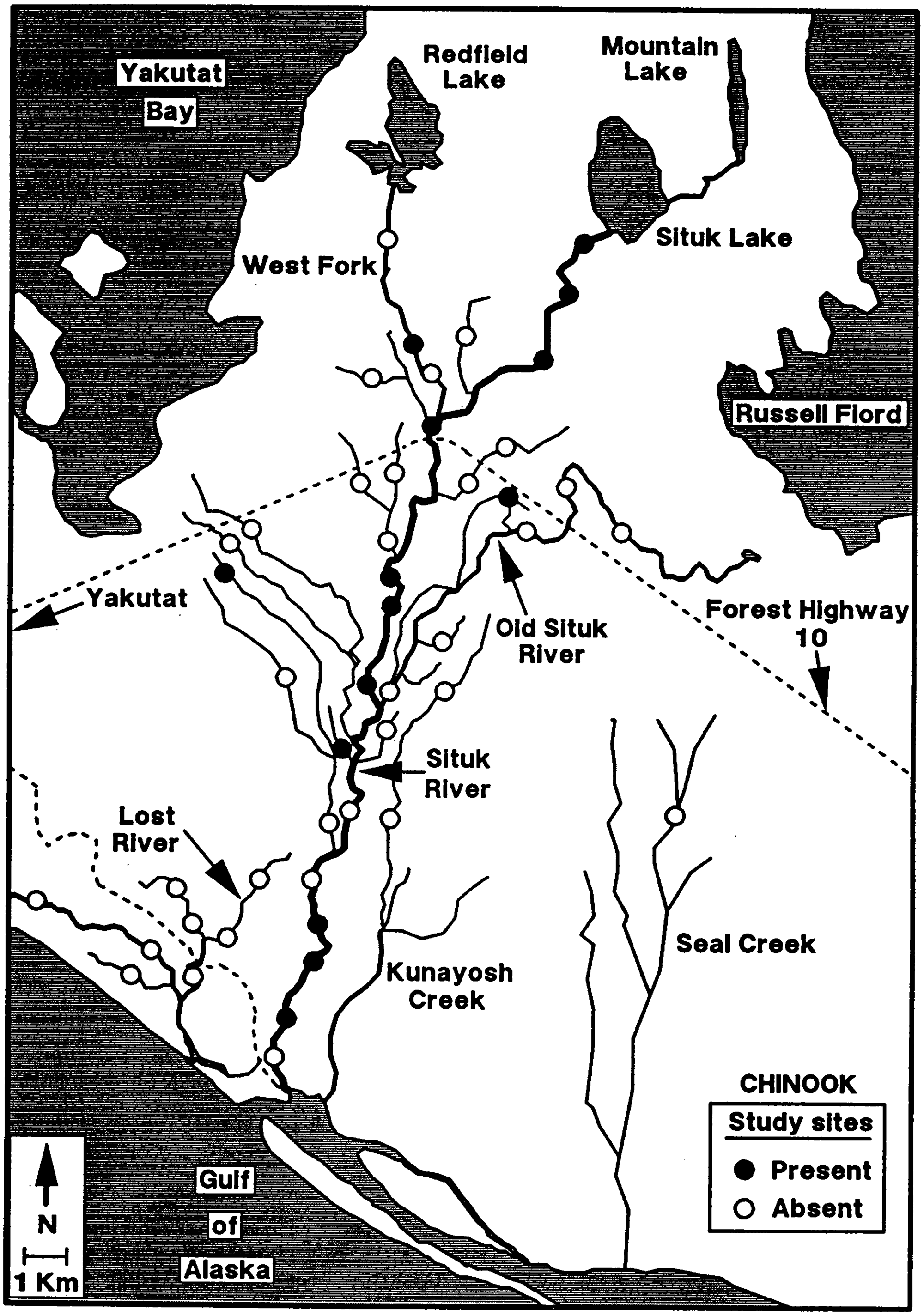

Figure 2.15—Location of study sites where juvenile chinook salmon were captured.

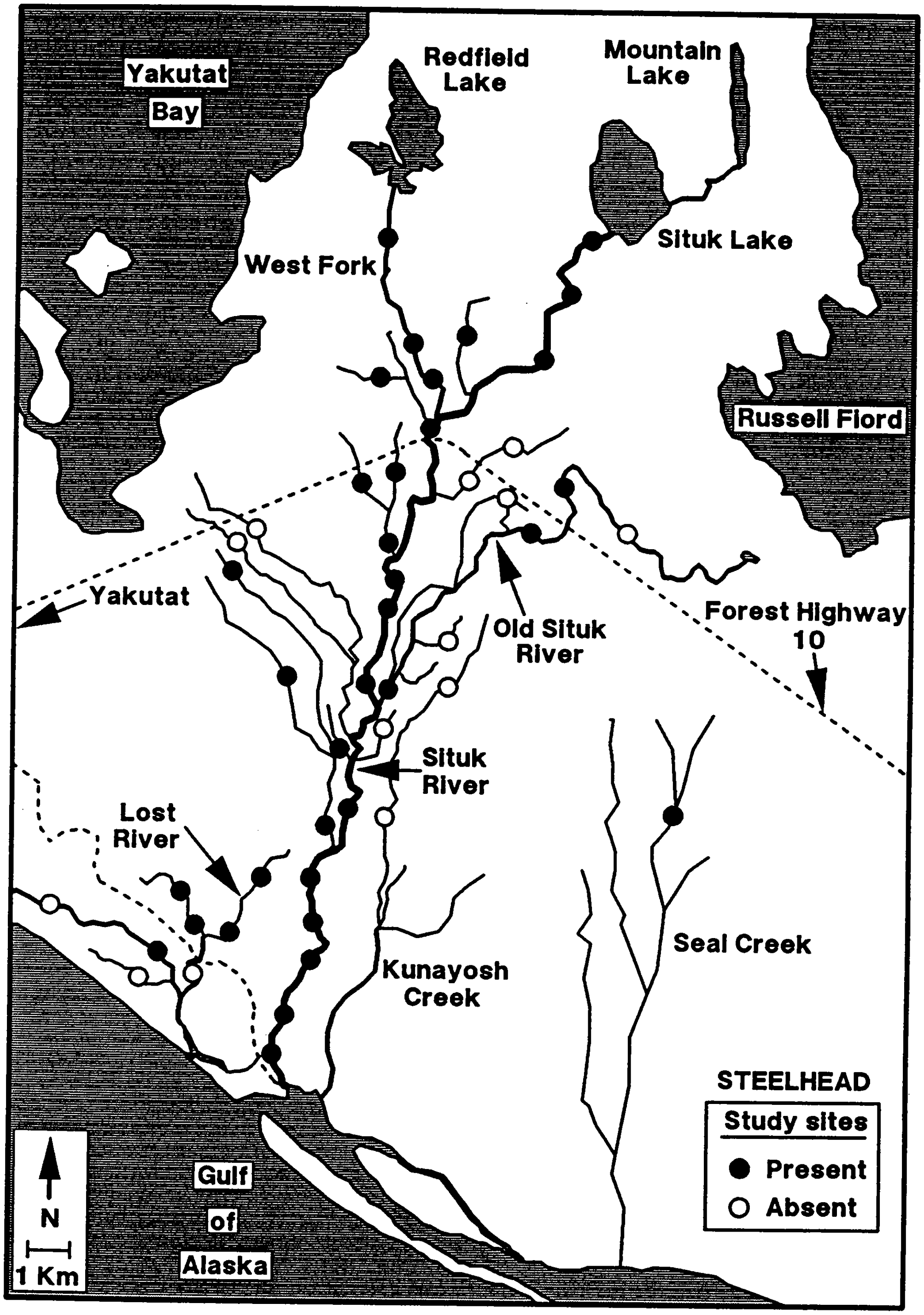

Figure 2.16—Location of study sites where juvenile steelhead were captured.

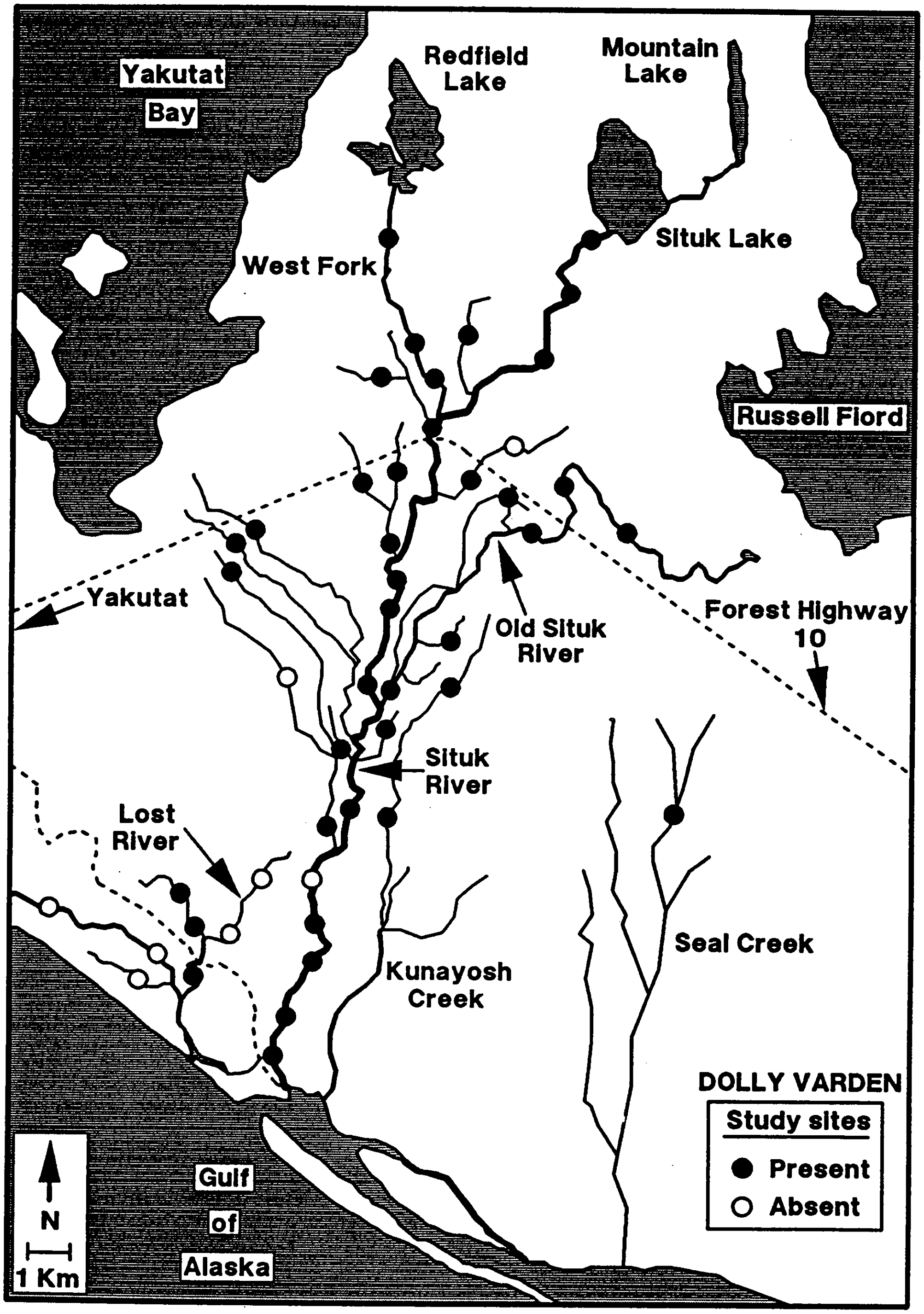

Figure 2.17—Location of study sites where juvenile Dolly Varden were captured.

STUDY 3.

SEASONAL UTILIZATION OF THE MAIN-STEM SITUK RIVER BY JUVENILE SALMONIDS

Rationale

Habitat in the main-stem Situk River will be heavily impacted by flooding. Knowledge of habitat utilization by juvenile salmonids in the main stem is important to determine potential losses from flooding and possible strategies for restoration.

Objectives

The objectives of this study were to determine the seasonal distribution, abundance, habitat use, and size of juvenile coho, sockeye, steelhead, and Dolly Varden in the main-stem Situk River. Similar data for chinook are presented in Study 4.

Summary of Results

The main-stem Situk River is an important summer rearing area for salmonids. In 1989 coho, steelhead, and Dolly Varden were common in the main stem from May through November, and sockeye were present from May to late July. In late November, coho and steelhead fry were still common, but parr, except Dolly Varden, were virtually absent. Fry often used channel edges with little cover; but parr primarily used willow edges and pools with abundant cover. Fish densities were higher in the upper river than in the lower river, probably because of warmer water and more abundant food near the Situk Lake outlet. The lower river is an important staging area for juvenile salmonids to acclimate to seawater while migrating to sea.

METHODS

Fish and habitat were sampled at two main-stem sites in the lower river and two main-stem sites in the upper river (Fig. 3.1) about every 2 weeks from 10 May to 22 September 1989 to estimate fish density and habitat use. We sampled these sites again on 30 November 1989 to determine fall-winter fish distribution but did not estimate fish density. At each site each sampling period except November, we sampled three habitat types (described in Study 2): three channel edges, one willow edge, and one debris pool. In November, we set baited minnow traps in willow edges (7 traps) and pools (15 traps) for 24 hours; channel edges were not seined because visual observations showed fish were absent. Habitat was measured during low flow and at low tide at lower river sites. Methods used to measure habitat, capture fish, and estimate fish density are in Study 2.

Each sampling period, a sample of fish of each species at each site was measured for FL and scaled to determine age (except Dolly Varden). Fry were separated from parr in the field by a predetermined cutoff size that increased seasonally from 50 to 75 mm. Age composition was determined by comparing scale ages with FL frequencies. Because assessment of fish and rearing habitat was the primary objective, migrating smolts were omitted from analysis.

RESULTS

Fish Abundance

Coho and steelhead fry densities (fish/100 m^2) were greater in the upper than in the lower river (Figs. 3.2, 3.3), whereas sockeye fry density was similar but low in both areas. Few Dolly Varden fry were caught, and data were omitted from analysis. Coho fry were caught from May through November, steelhead fry from late July through November, and sockeye fry from May through July. In the upper river, peak fry densities were 2,331 coho, 155 steelhead, and 13 sockeye; in the lower river, peak fry densities were 471 coho, 17 steelhead, and 14 sockeye. In November, twice as many fry were caught in the upper river as in the lower river (Table 3.1).

Parr densities were also usually greater in the upper river than in the lower river (Figs. 3.4, 3.5, 3.6). Coho, steelhead, and Dolly Varden parr were captured from May to November. In the upper river, peak densities were 281 coho, 82 steelhead, and 44 Dolly Varden; in the lower river, peak densities were 36 coho, 44 steelhead, and 35 Dolly Varden. Coho density peaked in the upper river in June and in the lower river in July; steelhead peaked in the upper river in August and in the lower river in June and July; and Dolly Varden peaked in the upper river in June and in the lower river in July. In November, parr were virtually absent, except Dolly Varden in the upper river (Table 3.1).

Habitat Utilization

Habitat characteristics differed among habitat types (Table 3.2). Average depth was greatest in debris pools (1.2 m) and least in channel edges (0.3 m). Average water velocity was greatest in willow edges (15 cm/s) and least in debris pools (10 cm/s). Cover was scarce in channel edges but was abundant in debris pools as large woody debris and in willow edges as overhanging vegetation and submerged roots.

Coho fry density differed significantly ($P < 0.05$; Friedman's test) among habitat types in the lower river but was similar ($P > 0.05$) among habitats in the upper river (Fig. 3.2). In the lower river, mean density was greater in willow edges (range, 0-471 coho) and debris pools (0-382) than in channel edges (0-82). In the upper river, mean density ranged from 2 to 1,442 in channel edges, 2 to 2,331 in willow edges, and 5 to 2,173 in debris pools. Density peaked earlier (May and June) in channel edges than in willow edges or debris pools (July). After July, density declined steadily in both the upper and lower river.

Densities of steelhead and sockeye fry were usually greatest in channel edges. Peak steelhead density was in channel edges in late July (upper river: 155 fish; lower river: 17 fish; Fig. 3.3). Peak sockeye density (14 fish) was in channel edges in late May, and few sockeye were in willow edges or debris pools.

Densities of coho, steelhead, and Dolly Varden parr differed significantly ($P < 0.05$; Friedman's test) among habitat types in both the upper and lower river. Parr densities were consistently greatest in willow edges or debris pools and least in channel edges (Figs. 3.4, 3.5, 3.6). In the upper river, peak densities of coho (281), steelhead (82), and Dolly Varden parr (44) were in willow edges. In the lower river, peak densities of coho (36) and Dolly Varden parr (35) were in debris pools, whereas peak steelhead density (44) was in willow edges.

Fish Size

Fry size of all species generally increased from May to September, but was similar in late September and November (Figs. 3.7, 3.8). An exception was coho in channel edges in the lower river where mean FL decreased sharply from 64 mm in late July to 39 mm in early August (Fig. 3.8). Monthly mean FL of fry (lower and upper river combined) increased from 36 to 64 mm for coho (May to November), 32 to 43 mm for sockeye (May to July), and 32 to 61 mm for steelhead (July to November).

Mean FL of fry within habitat types (combined sampling periods) was usually significantly ($P < 0.001$; t-test) greater in the lower than in the upper river (Table 3.3). The only exception was steelhead fry in channel edges; they were significantly ($P < 0.001$) larger in the upper than in the lower river. Among habitat types in both the lower and upper river, coho and steelhead fry were significantly ($P < 0.001$; F-test) larger in willow edges or debris pools than in channel edges.

Parr size also increased in most habitat types (Figs. 3.9, 3.10). Exceptions were steelhead parr in willow edges in the lower river and Dolly Varden parr in debris pools in the upper river. Mean FL of steelhead declined abruptly from 150 mm to 120 mm in mid-September, whereas mean FL of Dolly Varden decreased from 89 mm to 63 mm between late July and early September. Monthly mean FL (combined data for May to November) ranged from 60 to 87 mm for coho, 63 to 105 mm for steelhead, and 69 to 100 mm for Dolly Varden.

Within habitat types (combined sampling periods), coho, steelhead, and Dolly Varden parr were usually significantly ($P < 0.001$; t-test) larger in the lower than in the upper river (Table 3.4). An exception was that coho parr in willow edges were similar in size in the lower and upper river. In the lower river, coho, steelhead, and Dolly Varden parr were significantly ($P < 0.05$; t-test) larger in willow edges than in debris pools. In the upper river, steelhead parr were similar in size (90 mm) in both willow edges and debris pools. Mean FL of coho and Dolly Varden parr, however, differed significantly ($P < 0.001$; F-test) among habitat types in the upper river, with the smallest parr in channel edges.

Age Composition

The dominant age class in most sampling periods in both the upper and lower river was fry (Figs. 3.11, 3.12). All sockeye were fry, but nearly all Dolly Varden were parr. Coho parr were dominant (about 60%) only in debris pools in the lower river in May. Steelhead were 100% parr in May and June and 54-99% fry thereafter.

DISCUSSION

The main-stem Situk River provides important rearing habitat for juvenile salmonids. Channel edges are important nursery areas for newly emerged fry, particularly coho in May, June, and July; sockeye in May and June; and steelhead in July and August. Coho, steelhead, and Dolly Varden parr primarily used willow edges and debris pools—areas with abundant cover. Trapping in late November indicates that coho and steelhead fry use willow edges and debris pools in winter. Juvenile coho, steelhead, sockeye, and Dolly Varden occupied depth (0.3-1.5 m) and velocity (4-26 cm/s) ranges similar to those in other studies (Smith and Slaney 1980; Murphy et al. 1984; Thedinga et al. 1988; Bjornn and Reiser 1991).

Many coho and steelhead fry apparently moved from channel edges into willow edges and debris pools as they grew. As density of coho and steelhead fry decreased in channel edges, it increased in willow edges and debris pools. Other studies (Chapman and Bjornn 1969; Lister and Genoe 1970) have also shown that juvenile salmonids move from stream margins to areas of deeper, faster water as they grow.

Sockeye fry were not captured in the main stem after early July, and presumably migrated to the estuary. Many sockeye fry in the main stem were probably ocean type that originated from Old Situk River. Scale analysis shows that 94% of the sockeye escapement to Old Situk River (about 3,000 sockeye) have no freshwater annulus (Study 1). Number of ocean-type sockeye in the Situk estuary peaks in May and June, and most fish leave by late July (Study 5).

Coho was the most abundant species of fry in the main stem. This was expected, considering that coho escapement (25,000 adults)[17] is much higher than steelhead (5,000 adults; Schwan 1984) and chinook (2,000 adults; Bethers and Ingledue 1989), and most sockeye rear in lakes.

The greater densities of all species in the upper than in the lower river could be because of more suitable habitat upriver or because most spawning and wintering is in the upper watershed (Studies 1 and 6). Thus, as they emerge and disperse, more fry may occupy habitat close to the spawning areas in the upper river than farther downstream. Fry that are displaced by freshets (Scrivener and Anderson 1984; Sandercock 1991) or those unable to find and defend territories move to the lower river. This may explain why peak coho fry density was nearly three times greater in the upper than in the lower river. Similarly, parr migrating from wintering areas (tributaries and lakes) into the main stem may occupy nearby upriver areas first; some parr may eventually be displaced downstream as demands for space increase as fish grow (Sandercock 1991). Many parr may move downstream to staging areas as they begin to transform to smolts. Fish density may also have been greater in the upper than in the lower river because of greater food availability. Warmer water and abundance of seston in outlet flow from Situk Lake may provide more food in the upper main stem. Juvenile chinook, for example, grow to about 60 mm FL in the upper river by July before they migrate to the lower river, indicating favorable growth conditions (Study 4).

Density of fry, especially coho, declined from July to September. Mortality is a probable cause of the decline. Crone and Bond (1976) reported that mortality of coho was greatest (67-78%) in July and August of the first summer of life.

Fish density in the Situk River was generally higher than in other studies. In our study, however, density was estimated from specific habitats and not from an entire cross section of the river (this probably would have lowered our density estimates). In channel edges, coho fry density was higher (range, 0-1400 fish/100 m^2) and sockeye density lower (0-14 fish/100 m^2) in the Situk River than in the Taku River, Alaska (range, 0-5 coho/100 m^2, 17-40 sockeye/100 m^2; Thedinga et al. 1988). In pools, parr density was higher (0-280 coho/100 m^2 and 0-82 steelhead/100 m^2) in the Situk River than in an Oregon coastal stream (4-34 coho/100 m^2 and 13-24 steelhead/100 m^2; Hankin and Reeves 1988).

Seasonal differences in parr density between the lower and upper Situk River probably reflect migrations from wintering areas and subsequent migrations to the ocean. Coho and Dolly Varden parr were most abundant in the upper river from late May to late June, as they left wintering areas (e.g., Situk Lake) and moved into the main stem. Substantial numbers of coho, steelhead, and Dolly Varden parr reared in the lower river from late May to late July, but by

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[17]S. McPherson, Alaska Dep. Fish and Game, Commercial Fisheries Div., Southeast Region, 802 Third St., Douglas, AK 99824-0020. Pers. commun., 1992.

early August, numbers had declined, as some parr probably transformed to smolts and migrated to sea. By late November, any remaining parr had probably moved upstream to wintering areas. In Porcupine Creek, Alaska, juvenile coho migrated upstream from the estuary to freshwater areas in fall (Murphy et al. 1984).

Seasonal changes in fish size reflect growth and migration. In the lower river, immigration of late-emerging fry (yolk sac visible) probably accounted for the decrease in length of coho fry in channel edges in early August. Similarly, immigration of small parr and emigration of large parr, possibly as smolts, probably accounts for the decrease in length of steelhead parr in willow edges (September) and Dolly Varden parr in debris pools (late July-September). The size increase in fry in our study (coho, 36 to 64 mm; sockeye, 32 to 43 mm; steelhead, 32 to 61 mm) is similar to that in Idaho and Alaska (Everest and Chapman 1972; Thedinga et al. 1988). The size increase in coho parr in our study (60 to 87 mm) was similar to that in Sashin Creek, Alaska (70 to 88 mm; Crone and Bond 1976). The size range of steelhead (44-197 mm) and Dolly Varden (47-190 mm) parr in the Situk River was similar to that of steelhead in Idaho (60-160 mm; Everest and Chapman 1972) and Dolly Varden in Hood Bay Creek, Alaska (51-137 mm; Blackett 1968).

The larger size of juvenile salmonids in the lower river compared to the upper river is similar to results of other studies. Juvenile coho were larger in lower than in upper reaches of Porcupine Creek (Koski and Kirchhofer 1984). Lower reaches of rivers often have abundant food because of estuarine influence (Levy and Northcote 1982; Koski and Kirchhofer 1984) and may promote faster growth.

The largest parr often occupied willow edges rather than debris pools. In both the lower and upper river, coho parr were 3-5 mm larger in willow edges than in debris pools. In the lower river, steelhead and Dolly Varden parr were 8-12 mm larger in willow edges than in debris pools. Water velocity was usually faster in willow edges (15 cm/s) than in debris pools (10 cm/s); thus, larger parr may have occupied willow edges for increased exposure to food organisms (Chapman and Bjornn 1969).

Table 3.1—Catch of juvenile salmonids in baited minnow traps set 24 hours in the upper and lower Situk River on 30 November 1989. Two willow edges and two debris pools were sampled in each river area. (DV = Dolly Varden).

	Fry		Parr		
	Coho	Steelhead	Coho	Steelhead	DV
Lower river					
Willow edges	78	123	0	1	1
Debris pools	63	54	0	0	0
Upper river					
Willow edges	122	95	1	2	36
Debris pools	247	173	0	1	27

Table 3.2—Summer habitat characteristics of study sites in the upper and lower Situk River, 1989. (P = pool with large woody debris; WE = willow edge; CE = channel edge). Values for channel edges are the means of three channel edges.

	Lower river						Upper river					
	Site 1			Site 2			Site 1			Site 2		
	P	WE	CE	P	WE	CE	P	WE	CE	P	WE	CE
Habitat area (m^2)	300.0	79.8	74.0	213.0	73.5	74.0	194.7	86.1	74.0	229.5	88.2	74.0
Mean depth (m)	1.2	0.8	0.4	1.5	1.0	0.3	1.1	1.2	0.3	0.8	0.6	0.3
Max. depth (m)	2.6	1.1	0.6	2.7	1.8	0.4	1.8	1.5	0.5	2.5	0.9	0.5
Mean width (m)	7.5	3.8	2.7	7.1	3.5	2.7	5.9	4.1	2.7	5.1	4.2	2.7
Water velocity (cm/s)	4	13	7	7	7	7	4	12	17	23	26	13
Pieces of large woody debris	8	0	0	25	0	0	9	0	0	14	0	0

Table 3.3—Fork length (mm) of coho, steelhead, and sockeye fry by habitat type (combined sampling periods) in the upper and lower Situk River, May-September and November 1989. Data are means ± standard error; sample size is in parentheses. A dash indicates no fish were captured.

	Coho		Steelhead		Sockeye	
	Lower river	Upper river	Lower river	Upper river	Lower river	Upper river
Channel edges	50±0.6[a] (354)	39±0.2 (1637)	32±0.5 (94)	34±0.2[b] (614)	38±0.7[a] (132)	33±0.3 (123)
Willow edges	63±0.2[a] (1266)	53±0.3 (1637)	65±0.7[a] (108)	53±0.5 (319)	—	—
Debris pools	62±0.2[a] (1558)	52±0.3 (1921)	64±0.8[a] (102)	52±0.6 (329)	—	—

[a] Significantly ($P < 0.001$; t-test) larger in lower river than in upper river.

[b] Significantly ($P < 0.001$) larger in upper river than in lower river.

Table 3.4—Fork length (mm) of coho, steelhead, and Dolly Varden parr by habitat type (combined sampling periods) in the upper and lower Situk River, May-September and November 1989. Data are means ± standard error; sample size is in parentheses. A dash indicates no fish were captured.

	Coho		Steelhead		Dolly Varden	
	Lower river	Upper river	Lower river	Upper river	Lower river	Upper river
Channel edges	—	66±1.0 (120)	—	—	—	69±2.5 (14)
Willow edges	80±1.0 (128)	78±0.8 (274)	104±1.6* (183)	90±1.1 (316)	111±2.8* (57)	73±1.1 (151)
Debris pools	77±0.4* (466)	73±0.5 (671)	96±1.0* (494)	90±0.9 (595)	99±1.9* (203)	78±1.2 (221)

* Significantly larger ($P \leq 0.001$; t-test) in lower river than in upper river.

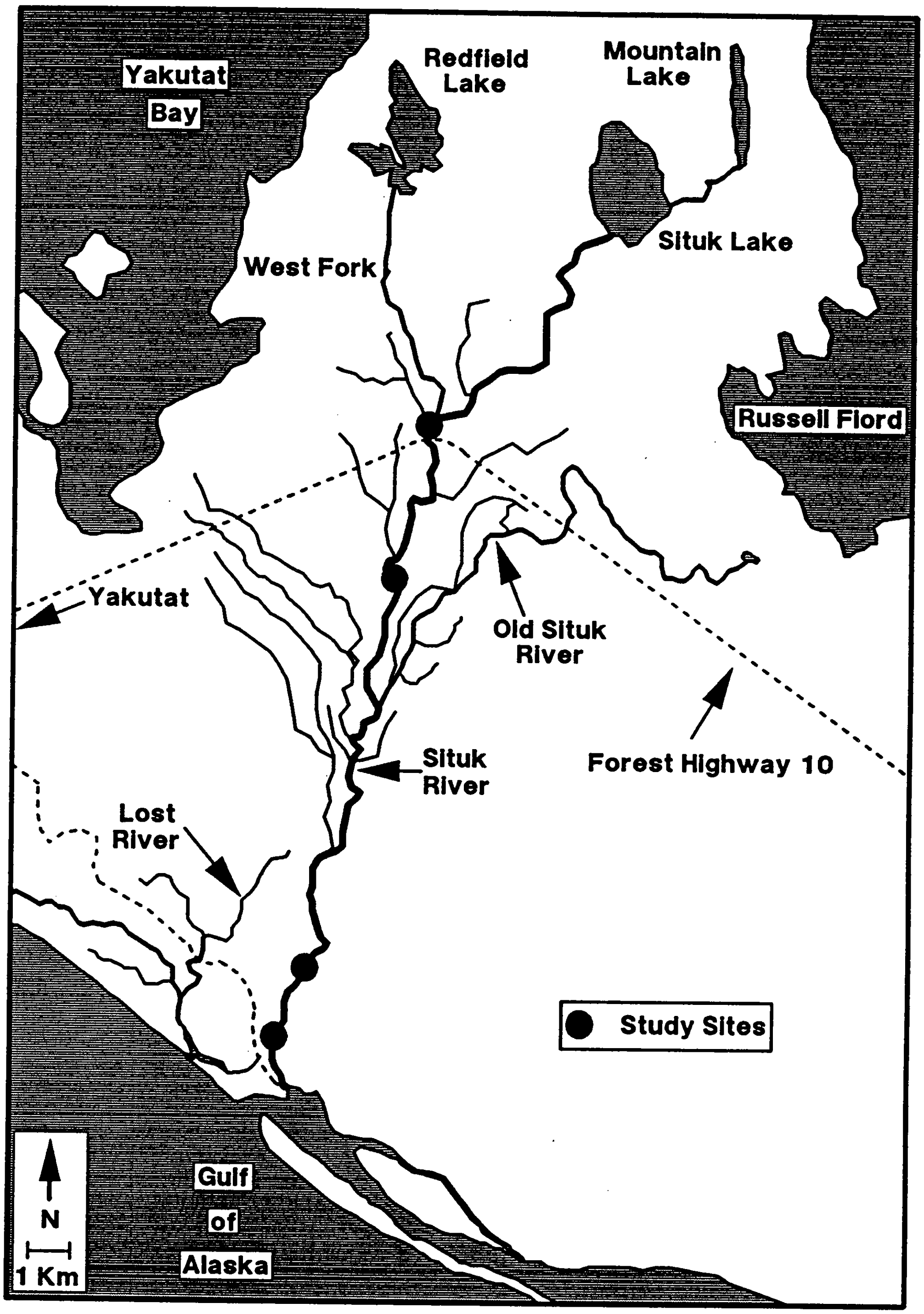

Figure 3.1—Sites sampled for juvenile salmonids in the upper and lower Situk River, May-September and November 1989.

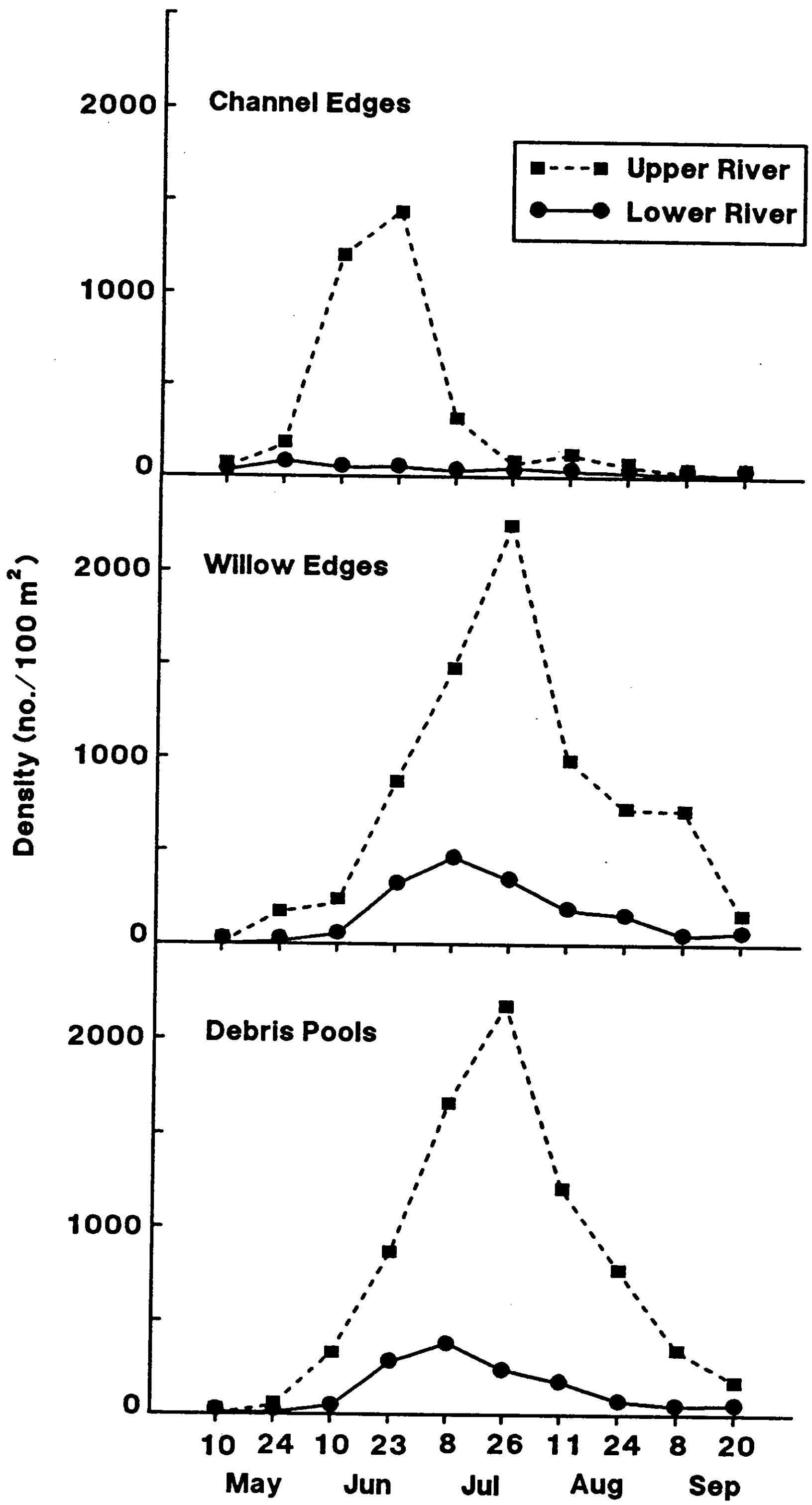

Figure 3.2—Mean density of coho fry by habitat type in the upper and lower Situk River, 1989.

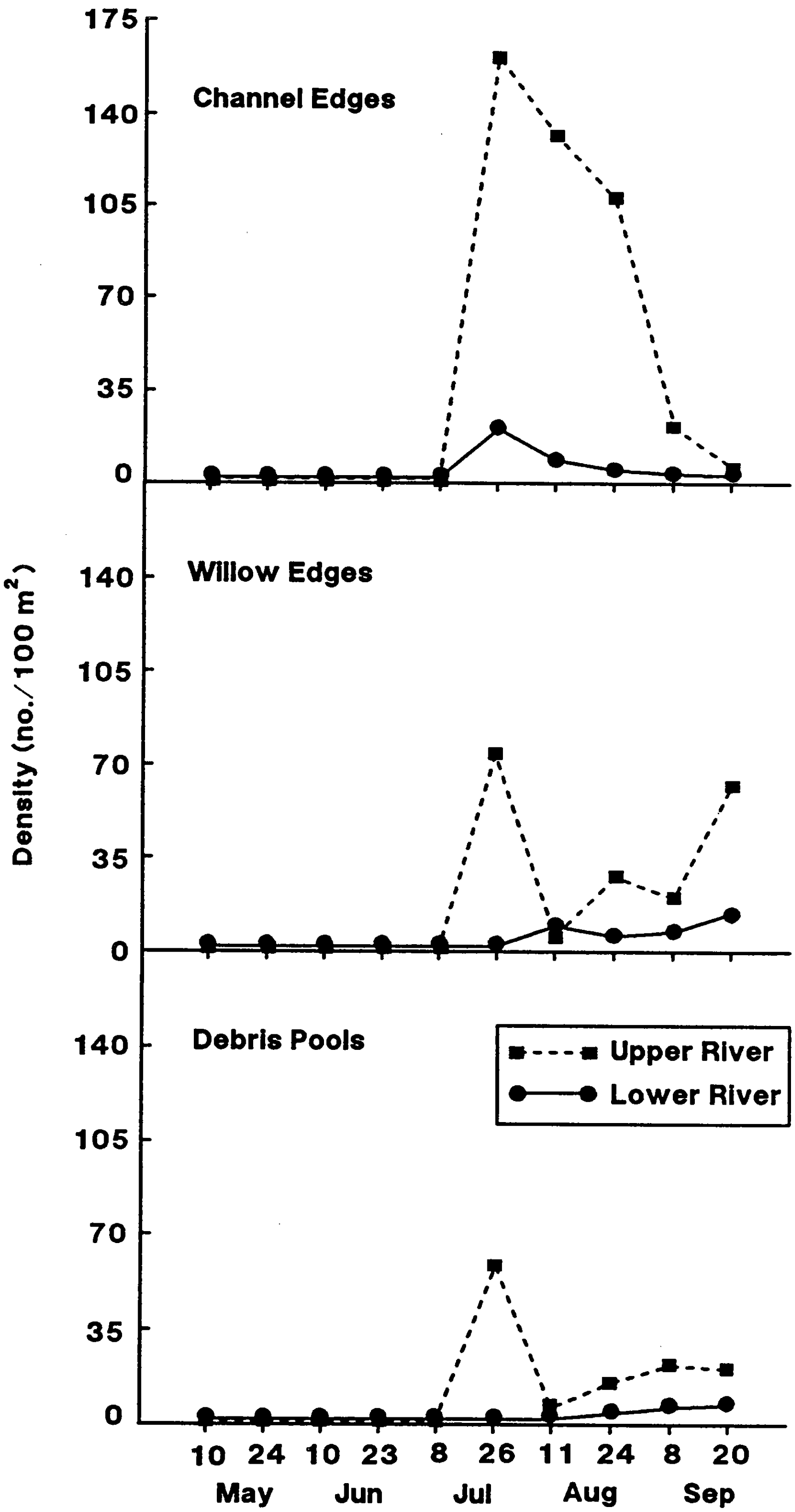

Figure 3.3—Mean density of steelhead fry by habitat type in the upper and lower Situk River, 1989.

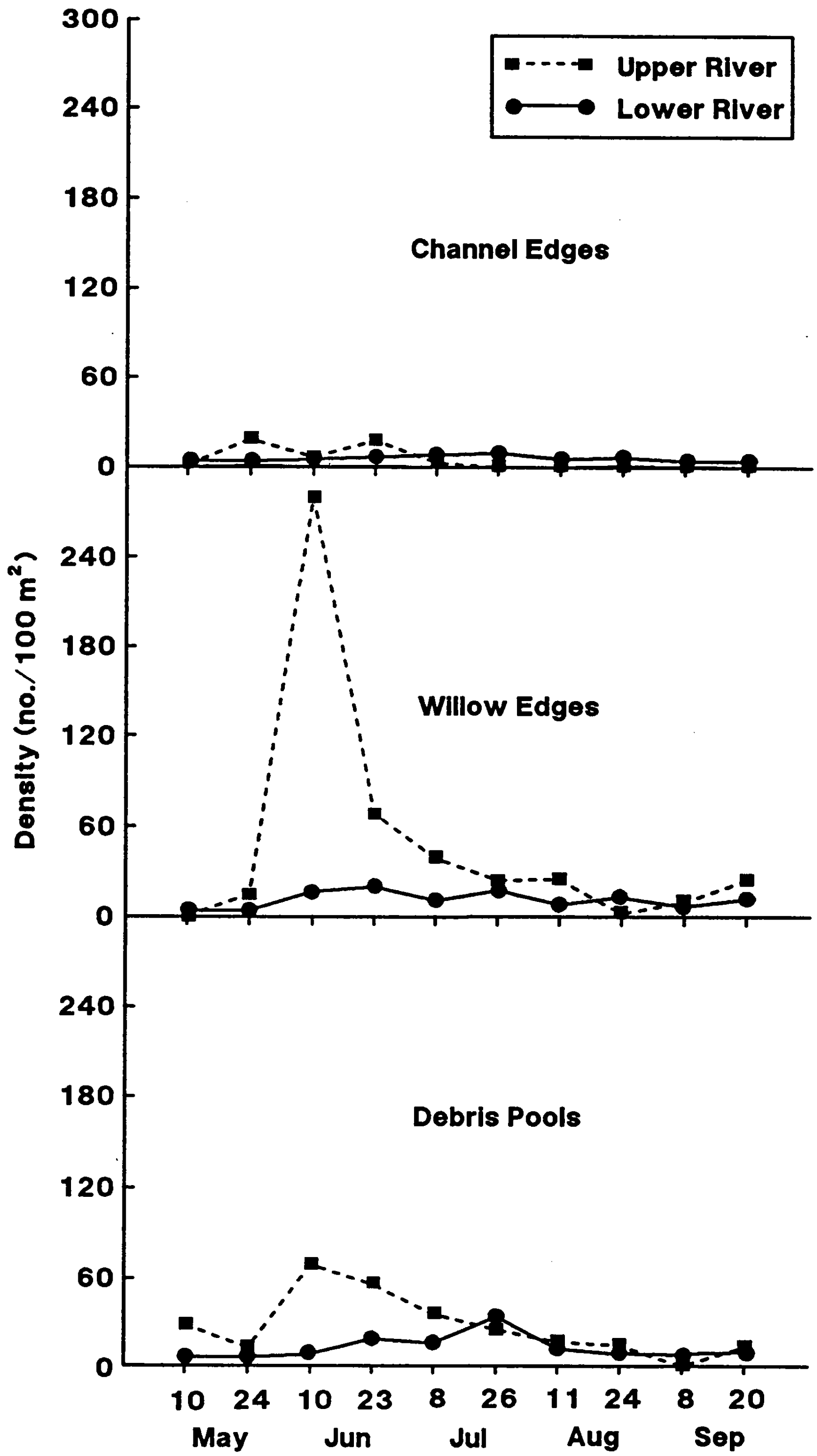

Figure 3.4—Mean density of coho parr by habitat type in the upper and lower Situk River, 1989.

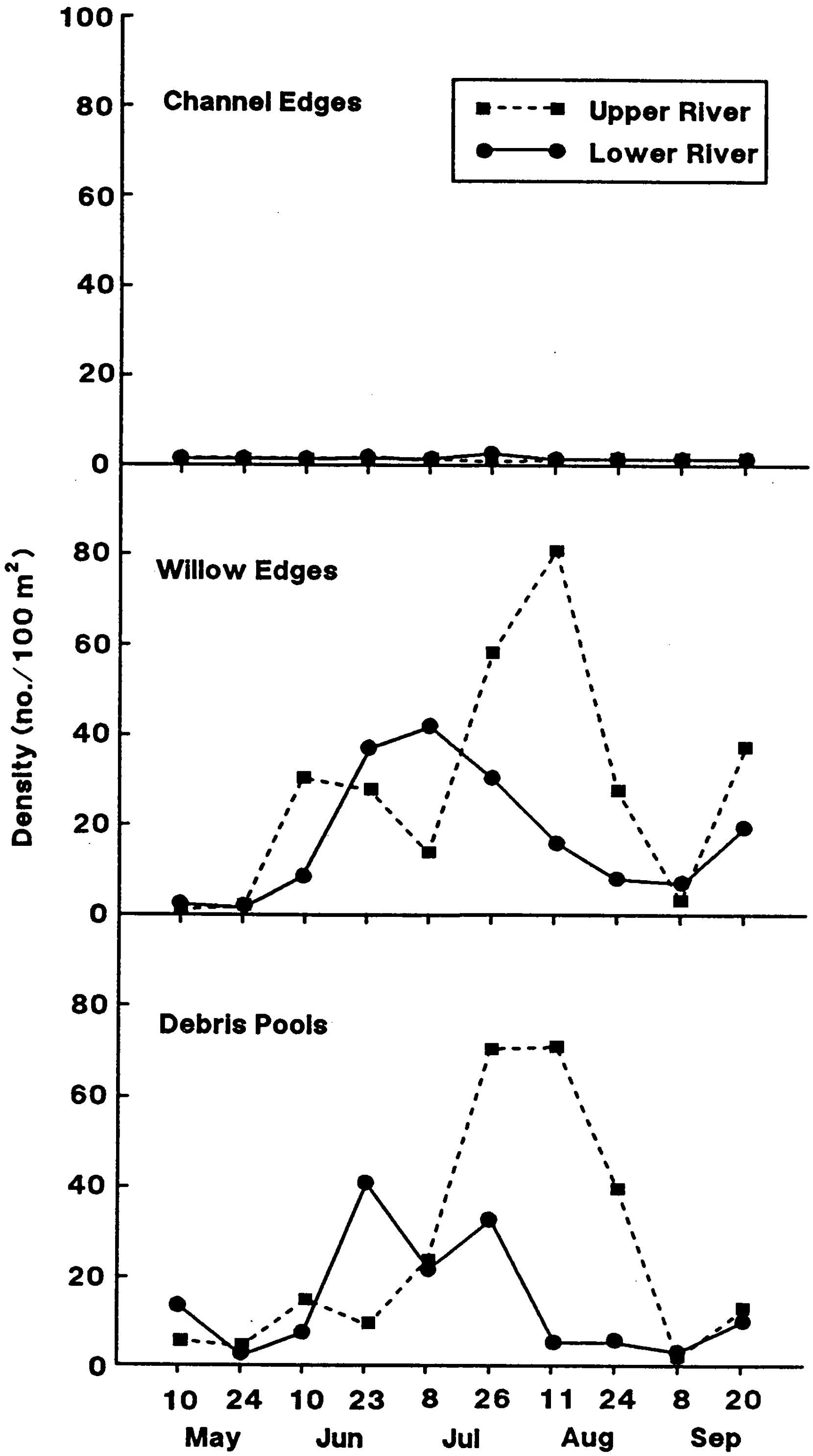

Figure 3.5—Mean density of steelhead parr by habitat type in the upper and lower Situk River, 1989.

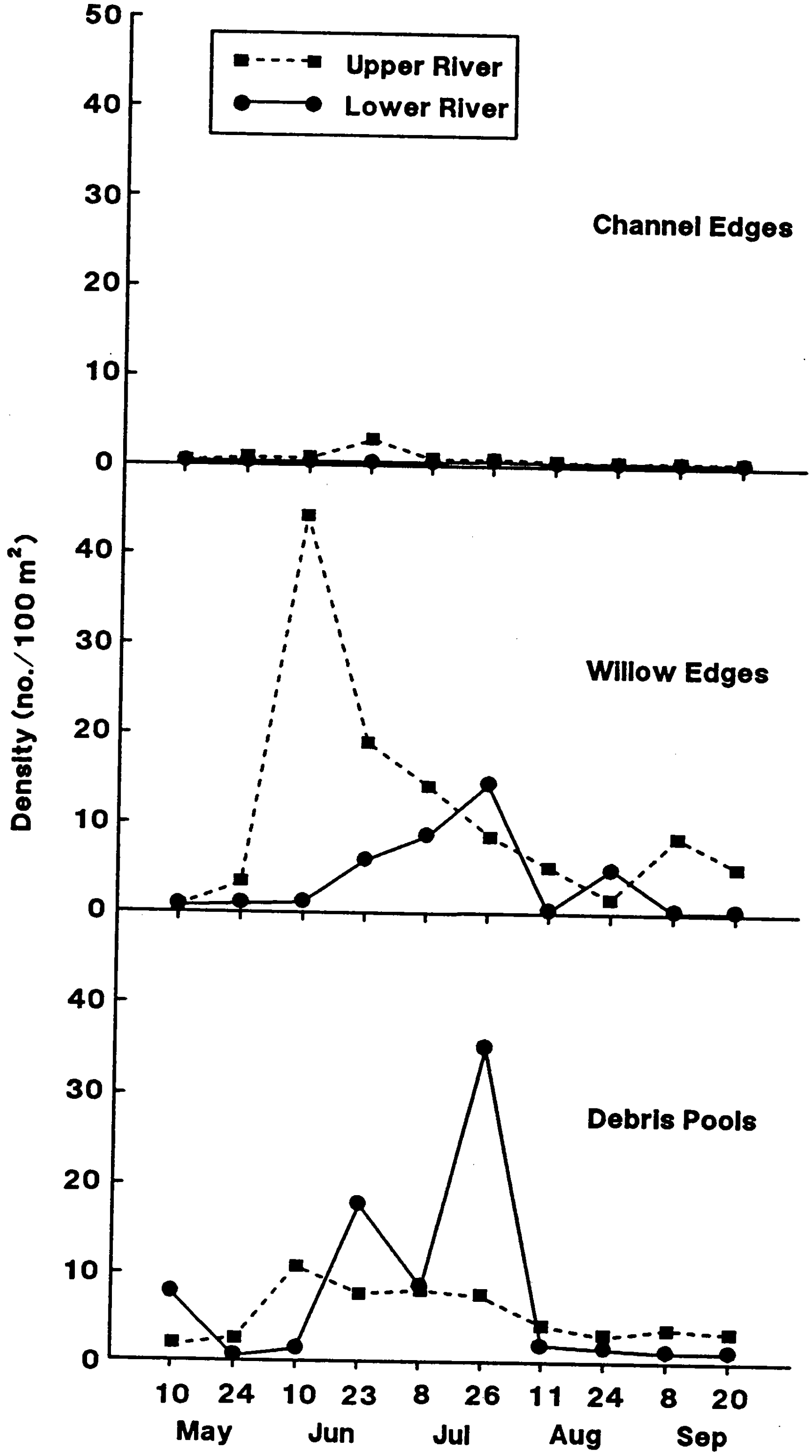

Figure 3.6—Mean density of Dolly Varden parr by habitat type in the upper and lower Situk River, 1989.

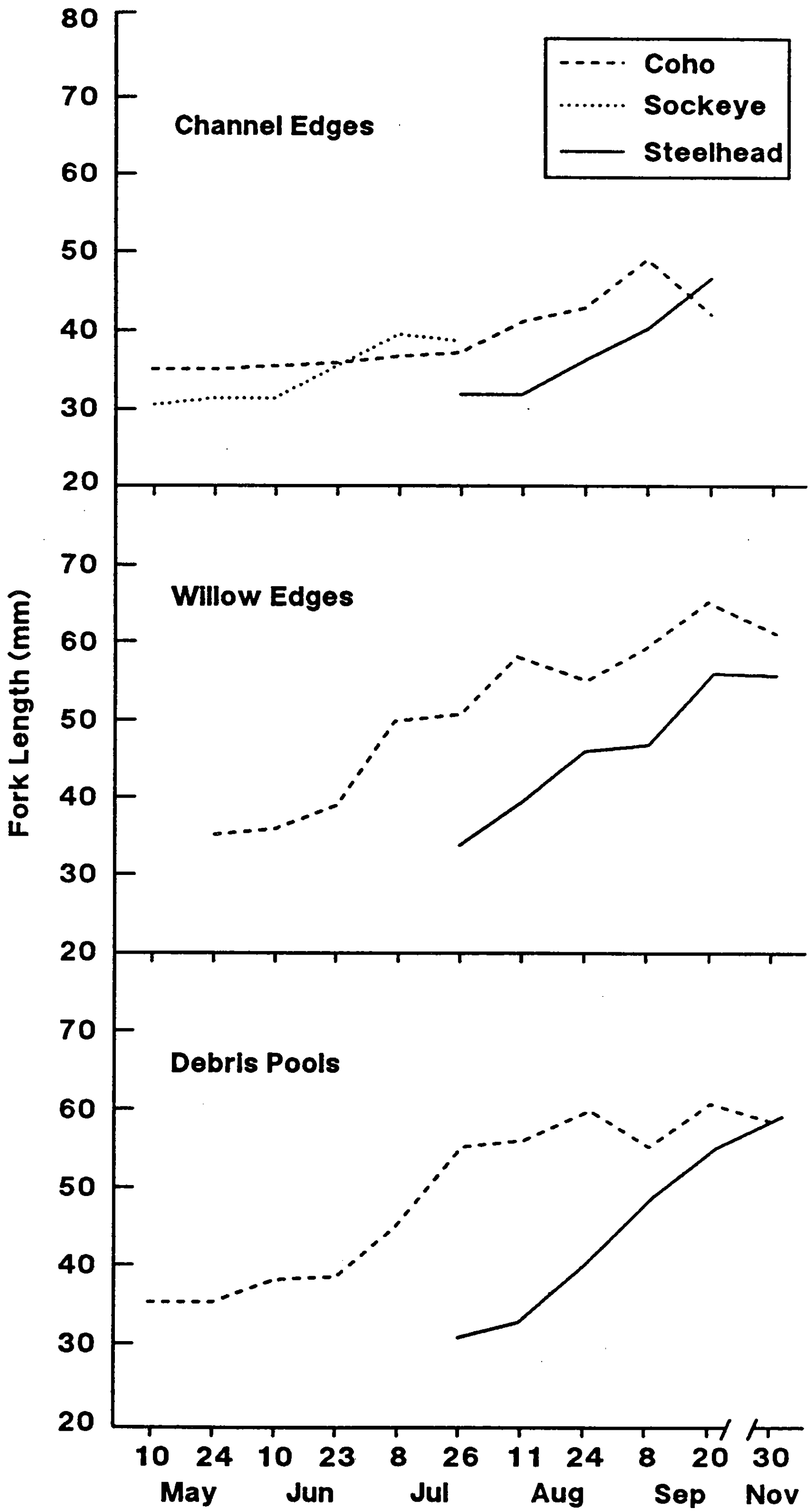

Figure 3.7—Mean fork length of fry by habitat type in the upper Situk River, 1989. Each data point represents at least seven fish.

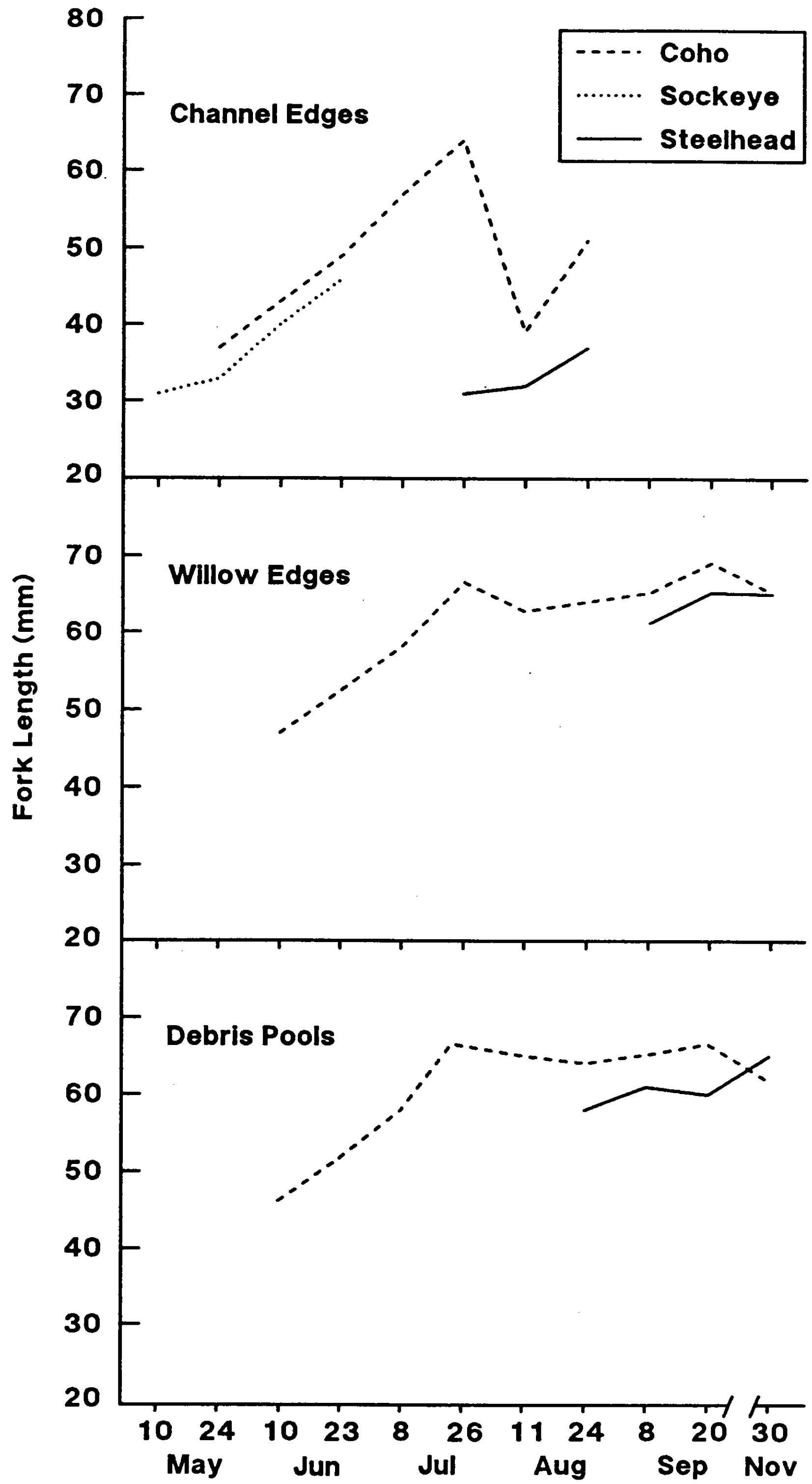

Figure 3.8—Mean fork length of fry by habitat type in the lower Situk River, 1989. Each data point represents at least seven fish.

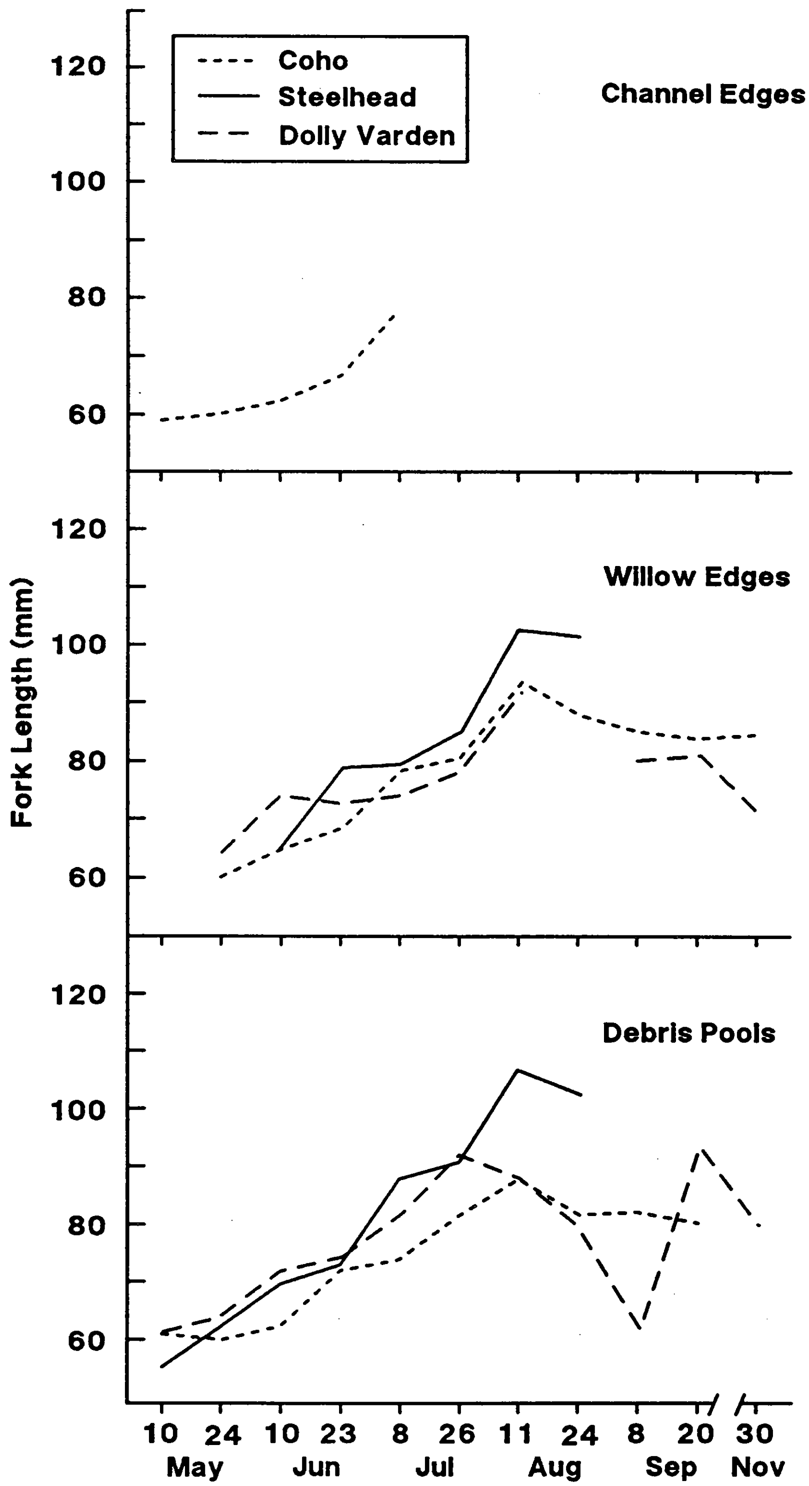

Figure 3.9—Mean fork length of parr by habitat type in the upper Situk River, 1989. Each data point represents at least seven fish.

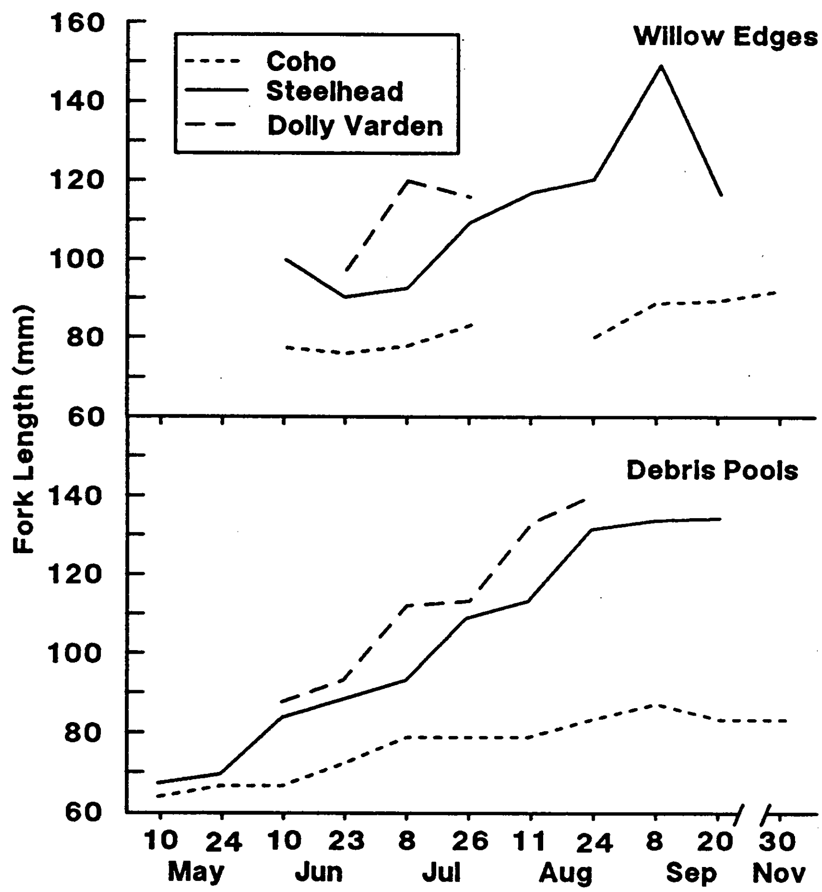

Figure 3.10—Mean fork length of parr by habitat type in the lower Situk River, 1989. Each data point represents at least seven fish.

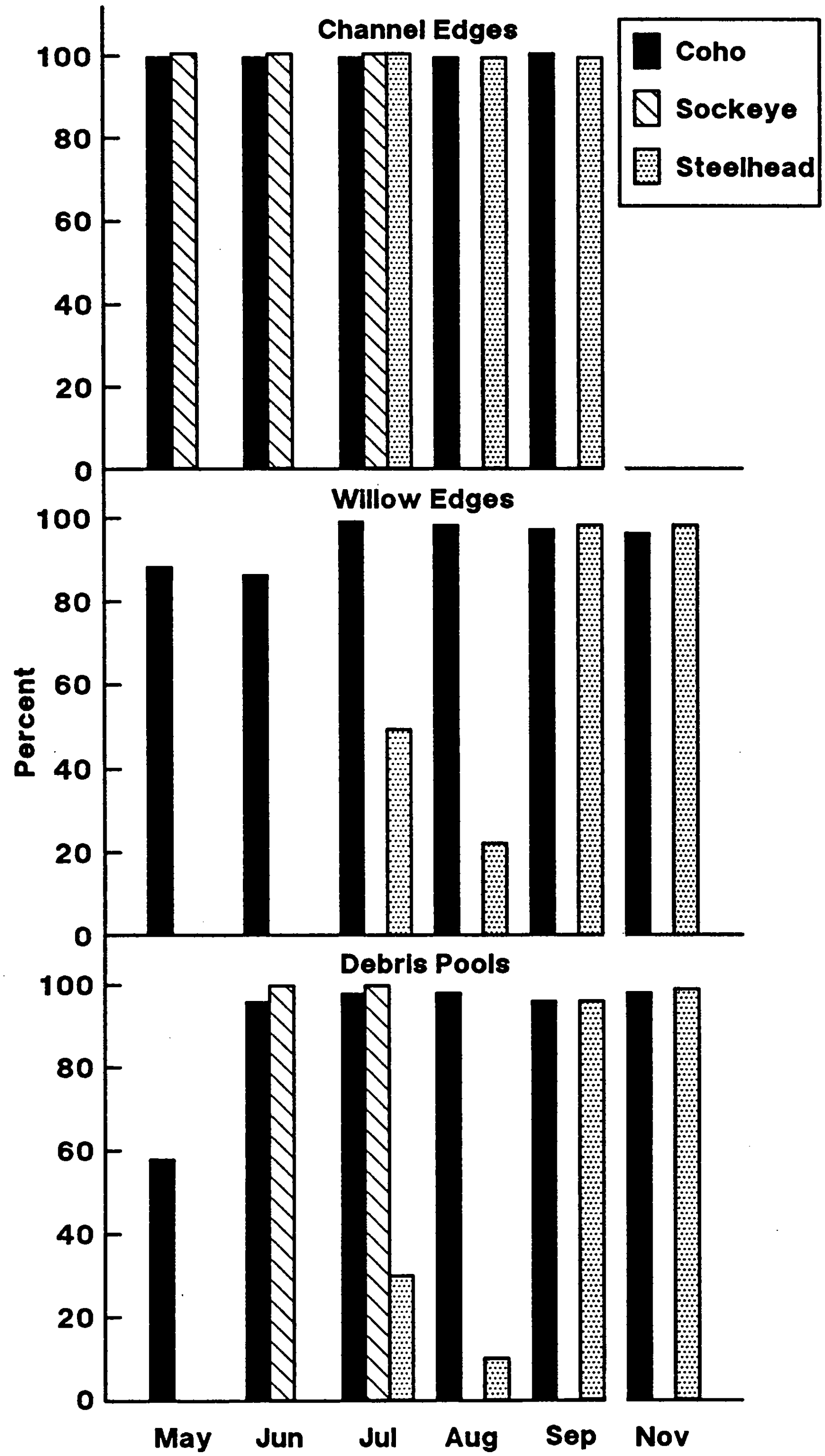

Figure 3.11—Percentage of fry by habitat type in the upper Situk River, 1989.

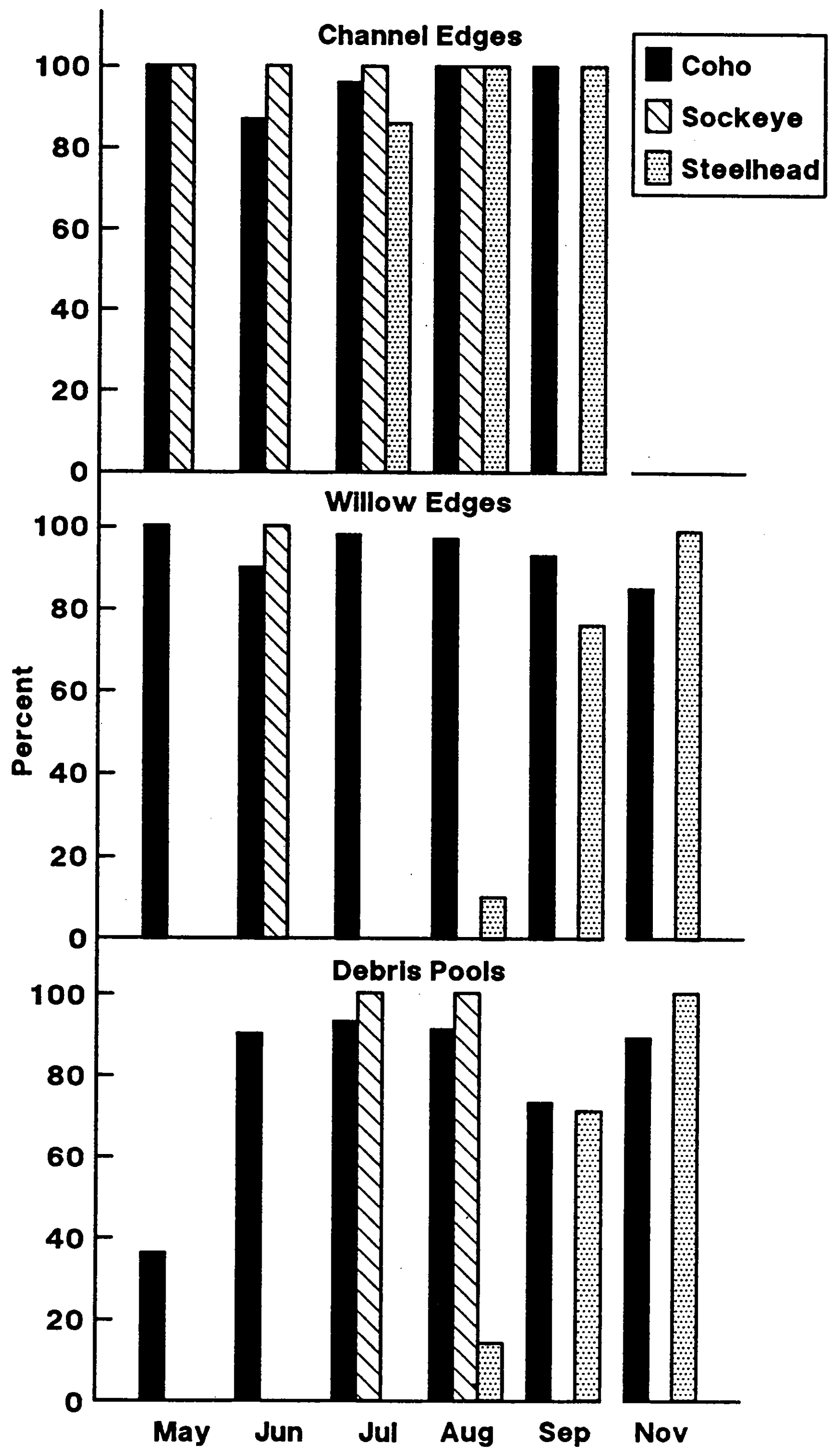

Figure 3.12—Percentage of fry by habitat type in the lower Situk River, 1989.

STUDY 4.

LIFE-HISTORY OF OCEAN-TYPE JUVENILE CHINOOK SALMON IN THE SITUK RIVER

Rationale

Unique stocks in the Situk River, such as ocean-type chinook, may be lost as a result of flooding. Therefore, freshwater life-history information on juvenile chinook is critical in any effort to conserve this stock.

Objectives

The objectives of this study were to document the existence and describe the life history of ocean-type chinook in the Situk River by examining the distribution, abundance, habitat use, migration and residence timing, seawater tolerance, and size of juveniles before seaward migration.

Summary of Results

Most (>95%) chinook in the Situk River migrate to sea at age 0. Chinook primarily occupied main-stem habitats (channel edges in spring, pools and willow edges in summer) in 1989. Peak density in the upper and lower main stem was 96 and 76 fish/100 m^2, respectively. Chinook migrated downstream in two phases: a spring dispersal of emergent fry, and a summer migration of presmolts. Chinook marked in the upper river in late June and July were recaptured 20 km downstream in the lower river in late July. Marked chinook remained in the lower river for up to 34 days. Mean fork length of chinook in the lower river increased from 40 mm in May to 80 mm in early August. By late August, chinook had emigrated from the lower river at a size of about 80 mm. Fish of this size could tolerate seawater and had the physical appearance of smolts. The results of this study have been reported elsewhere (Johnson et al. 1992).

METHODS

Juvenile chinook were sampled at 55 sites in the Situk River and neighboring watersheds (Fig. 4.1). Sites were either repetitive (8) or distribution (47) sites; repetitive sites were sampled several times in 1988-89 to determine seasonal changes in chinook size and abundance, whereas distribution sites were usually sampled only once (March-October) from 1987 to 1989 to document presence or absence of chinook. In 1988, repetitive sites included four in the lower river and one in the upper river; sites were sampled about every 3 weeks from 13 April to 1 September (sampling at the upper river site did not begin until mid-May). In 1989, repetitive sites included two in the lower river and two in the upper river; sites were sampled about every 2 weeks from 10 May to 22 September, and once in late November. Repetitive sites were different in 1988 and 1989, except for one site in the lower river. Similar habitats were sampled and comparable methods (e.g., seines, minnow traps) were used at both repetitive and distribution sites.

In 1988 at repetitive sites, relative abundance was determined from total catch of chinook by habitat type. At least one channel edge and one debris pool (habitats defined in Study 2) and one main-stem channel pool (deep area of main-river flow, usually void of LWD) were usually sampled at each of the five sites. Chinook in channel edges were captured with a pole seine (Study 2). Chinook in debris pools were captured with minnow traps: 5-10 traps spaced 3-5 m apart throughout a pool and set for 30 min. Chinook in main-stem channel pools were captured with a beach seine: 28 m long, 3 m deep, with 13-mm stretch mesh on the wings, and a central bag of 6-mm stretch mesh. Researchers on foot set the seine parallel to and 3-4 m from shore and retrieved it from shore. Only one pass with a seine was made at channel edges and main-stem channel pools.

We sampled more intensively at repetitive sites in 1989 than in 1988 primarily to 1) determine population density, 2) determine seasonal changes in density in the upper and lower river, and 3) document the emigration of chinook from the river. During each sampling period in 1989, three channel edges, one debris pool, and one willow edge were usually sampled at each of the four repetitive sites. Fish were captured, populations estimated, and habitat was measured as described in Studies 2 and 3. Differences in habitat characteristics (water depth, etc.) among habitat types in the upper and lower river are described in Study 3.

To assess fish residence time and movement between the upper and lower river in 1989, some juvenile chinook were tattoo marked with a Panjet medical instrument (Fig. 4.2). A dye (Alcian Blue at a concentration of 65 mg/ml) was injected under pressure into the caudal fin rays of anesthetized fish from a distance of about 3 mm. After injection, each fish was dipped in water and the mark was checked; if the mark was not clear, the fish was remarked. Fish from upper-river sites were marked in the upper lobe of the caudal fin (UC = upper caudal), whereas fish from lower-river sites were marked in the lower lobe (LC = lower caudal) (Fig. 4.3). All marked fish were released at their capture site. Downstream movement of juvenile chinook was also monitored by periodically placing a fyke net (1.2 m x 1.2 m; 6-mm mesh) in the main-stem Situk River from April to late June 1989. The fyke net was set overnight (12 h) in the upper river (17 km upstream from the mouth, Fig. 4.1), about every fifth night.

The osmocompetence of chinook was tested with salinity tolerance bioassays. From May to July 1988, chinook were collected in the lower and upper river and placed in 60-L plastic containers filled with aerated water at 0, 26, 28, and 30‰ salinity at ambient temperature for 96 h. Ocean water was mixed with fresh water to obtain desired salinity. To avoid overcrowding, fewer than 20 fish were placed in each container. Dead fish were removed every 12 h.

A random sample of juvenile chinook captured during each sampling period was measured for FL. Scale samples for ageing were taken from a range of sizes in the catch.

In mid-July 1989, over 10,000 juvenile chinook were captured in the lower river, coded-wire tagged (Fig. 4.4), adipose (AD)-clipped, and released. Mean growth was determined from recaptured AD-clipped fish in the lower river in early August 1989.

RESULTS

Distribution

Juvenile chinook were captured in only 22 of 55 sites sampled in the Situk River and neighboring watersheds (Fig. 4.1). Most sites with chinook were restricted to or near larger streams: 16 were on the main-stem Situk River (average width 27 m), and 3 of the 6 remaining sites were on tributaries approximately 200 m upstream of the main-stem Situk River. Chinook were not captured in two main-stem distribution sites (Fig. 4.1), probably because these sites were sampled after late July and most chinook had already migrated to sea. Other distribution sites were accessible and contained numerous juvenile salmonids; however, chinook were probably absent from most because of small stream size (average width 8 m).

Seasonal Abundance in Upper and Lower River

In 1988, juvenile chinook were present at the upper river site from mid-May to 1 September. Chinook catch was greatest in mid-May, when nearly 50 fish were captured. In 1989, chinook were present at the upper river sites from mid-May to late September; peak density was 96 fish/100 m^2 in late June (Fig. 4.5).

In 1988, juvenile chinook were present at the lower river sites from mid-April to early August. Total catch of chinook was greatest in late June, when nearly 300 fish were captured. In 1989, chinook were present at the lower river sites from late May to late September, except for a few newly emerged chinook captured in mid-March during distribution sampling. In 1989, density of chinook peaked in lower river sites in late July (76 chinook/100 m^2; Fig. 4.5).

Chinook abundance declined by late summer: catches declined to zero in the lower river sites and one in the upper river site on 1 September 1988. Density declined to only 0.03 fish/100 m^2 in the lower river and 0.55 fish/100 m^2 in the upper river on 20 September 1989 (Fig. 4.5). In November 1989, no chinook were found in either the upper or lower river.

Habitat Utilization

Chinook density did not differ significantly ($P > 0.05$; Friedman's test) between lower-river habitat types, but did differ significantly ($P < 0.05$) between upper-river habitat types. Few chinook were in the lower river in May, June, August, and September 1989. However, chinook were abundant in July; mean density ranged from 43 fish/100 m^2 in debris pools to 141 fish/100 m^2 in willow edges (Fig. 4.6). Recently emerged chinook (mean FL 43 mm), captured primarily along channel edges in May 1989, indicated that populations had not yet reached equilibrium among habitat types in the upper river (Fig. 4.6). Beginning in June, however, as chinook grew (mean FL 56 mm) in the upper river, most occupied pool or willow-edge habitats, and few were found in channel edges (Fig. 4.6). In the upper river, the highest chinook density observed was in debris pools in July (mean 164 fish/100 m^2).

Migration and Residence Timing

After emergence, chinook either dispersed downstream or remained in the upper river until July. Juveniles (mean FL 43 mm) dispersing downstream were captured by fyke net from April through June 1989, with peak catches in May (Fig. 4.7)—however, most juveniles remained in the upper river. In July, a major downstream migration of chinook presmolts to the lower river occurred: density in the lower river increased sharply from 3 fish/100 m^2 to 76 fish/100 m^2 (21 June-25 July 1989) while density in the upper river decreased from 96 fish/100 m^2 to 40 fish/100 m^2 (Fig. 4.5). Further evidence of the downstream migration was the recapture of marked fish—37 of 882 chinook that were Panjet marked (UC) 19 June-7 July 1989 in the upper river were recaptured. Most (30) were recaptured approximately 20 km downstream in the lower river on 16-20 July (Table 4.1); the rest (7) were recovered in the upper river.

Chinook were present in the lower river in substantial numbers for about 48 days (21 June-9 August 1989; Fig. 4.5). Recovery of Panjet-marked fish indicated that some chinook reared in the lower river for at least 8 days and possibly as long as 34 days—69 of 229 chinook marked in the lower river on 22 June and 8 July 1989 were recaptured in the lower river between 8 and 26 July (Table 4.1). Chinook did not migrate from the lower river to other areas in the Situk River watershed. Sampling of several distribution sites (including Situk Lake), and repetitive sites after mid-August, captured few chinook. Most chinook captured in the lower river in summer appeared to be smolts.

Seawater Tolerance

Chinook from the lower river tolerated seawater earlier in the year than chinook from the upper river. Survival in 26-30‰ salinity seawater was 91% in mid-May and 100% in early June for chinook from the lower river, versus 31% and 62%, respectively, for chinook from the upper river. By mid-July, however, survival was 100% from both the upper and lower river. Survival of fish of similar length from the upper and lower river differed significantly ($P < 0.05$; Chi-square). In early June, survival in 26-30‰ salinity seawater for 40-49 mm FL chinook was 100% for fish from the lower river compared to only 64% for fish from the upper river (Table 4.2). Survival of ≥50 mm FL chinook did not differ significantly ($P > 0.05$) between the upper (90%) and lower (100%) river; in mid-July, most chinook in the river were >60 mm FL, and survival was 100%.

Age and Size

Of the 250 chinook aged in 1988 and 1989, 98% were age 0 and 2% were age 1 (Table 4.3). Two of the five age-1 chinook were captured in June and three in July.

Chinook were larger in the lower river than in the upper river (Fig. 4.8). Most chinook reared in the upper river to about 60 mm FL before migrating to the lower river. For example, some larger chinook in the upper river in May 1989 apparently migrated to the lower river in June (range 56-76 mm FL; Fig. 4.8). Most chinook captured in the lower river were ≥60 mm FL (99% in 1989; 77% in 1988). Chinook reared in the lower river until they were approximately 70-80 mm FL.

Mean size of chinook doubled in the lower river from nearly 40 mm in May to about 80 mm in early August; mean size in the upper river was less than 70 mm in early August (Fig. 4.9). Within most sampling periods, chinook in the lower river were 5-17 mm longer than chinook in the upper river. Mean size in the lower river, just before abundance declined, was 70 mm in late June 1988 and approximately 80 mm in late July 1989.

In late July 1989, chinook in the lower river grew approximately 0.57 mm/day. Based on the recapture of AD-clipped fish, mean FL in the lower river increased from 80 mm ($n = 423$) on 16-20 July (18 July; median release date) to 88 mm ($n = 103$) on 1 August.

DISCUSSION

Because of the apparent presence of a freshwater annulus on adult scales—which can be difficult to identify (Koo and Isarankura 1967)—most (>97%) chinook in the Situk River have been classified by fishery workers as stream-type fish (McBride 1986; Riffe et al. 1987). Based on our study of juveniles in the river, we believe that most adult Situk chinook have been misidentified as stream-type. It could be argued that the disparity in freshwater age could result from only age-1 smolts (2% of the population) surviving to adulthood and poor survival of ocean-type fish (98% of the population). Recent studies, however, indicate that the total chinook smolt yield from the Situk River is approximately 67,000 fish (Study 7) and the approximate 2,500 annual adult run could not possibly be produced by 2% of the smolt yield, even with 100% survival. The ocean-type chinook we captured in the lower Situk River had the morphological appearance of smolts, could tolerate seawater, and eventually disappeared from the river; presumably they migrated to sea. Most chinook apparently do not winter within the Situk River watershed, because few age-1 fish were present in 1988 or 1989. Kissner (1986) suggested a similar seaward migration of ocean-type chinook from the Situk River in 1983 and 1984 based on juvenile sampling.

Chinook primarily occupied main-stem habitats until they apparently emigrated from the Situk River, similar to fall chinook in Sixes River, Oregon, which occupy main-stem habitats until early summer, when they migrate to the estuary (Reimers 1971; Stein et al. 1972). In spring in the upper Situk River, recently emerged chinook were often present along channel edges. By June, as fish increased in size, they moved into deeper, faster water with more cover (willow edges and debris pools). Lister and Genoe (1970) and Stein et al. (1972) also observed the shift in habitat utilization of juvenile chinook salmon from stream margins in spring to midstream or areas of faster water in summer. Chinook in the Situk River occupied areas with water velocity (range, 4-26 cm/s) and depth (range, 0.3-1.5 m) similar to areas utilized by chinook in other studies (Everest and Chapman 1972; Reiser and Bjornn 1979; Hillman et al. 1987).

Peak densities of chinook in the upper (96 fish/100 m^2) and lower (76 fish/100 m^2) river were similar to density in other studies. Murray and Rosenau (1989) reported maximum chinook density of 6-68 fish/100 m^2 from May to June in tributaries of the Fraser River, British Columbia. Chinook density in summer of 10-75 fish/100 m^2 were reported in some Idaho rivers (Everest and Chapman 1972; Hillman et al. 1987). In the Stikine River, Alaska, chinook density was 2-95 fish/100 m^2 from May to October[18]. In the glacial Taku River, Alaska, however, chinook density (0-8 fish/100 m^2; Murphy et al. 1989) was much lower than in the Situk River.

Chinook in the Situk River migrated downstream in two phases: a dispersal in spring after emergence followed by a mid-summer migration. The fyke net site was in mid-upper river, and catches probably were emergent fry redistributing to suitable rearing areas. Most chinook did not enter the lower river, however, until July, which suggests that fish remained in the upper river or migrated slowly downstream. Rearing migrations where chinook move slowly downstream throughout the summer have been reported by Ewing and Birks (1982) and Beauchamp et al. (1983). Once chinook start downstream, they either migrate directly to the estuary or stop and rear in the stream for a few weeks to a year or more (Healey 1991). The rapid increase in chinook abundance during July in the lower river with a concurrent decrease in the upper river, and the recapture of marked (UC) fish in the lower river, documents a major downstream migration. After reaching the lower river, some marked (LC) chinook remained there at least 8 days to nearly a month. Residence of 1-4 weeks in the lower river offers benefits of additional food similar to estuarine conditions (Levy and Northcote 1982) and a period of seawater acclimation.

Most ocean-type chinook disappeared from the Situk River by September and apparently emigrated to sea. Just before seaward migration (late June to late July), chinook mean size was 70-80 mm FL; for fish ≥60 mm FL from both the upper and lower river, survival in seawater was 100%. Weisbart (1967) reported that 70 mm FL was the approximate size at which juvenile chinook can tolerate full-strength seawater. Thus, ocean-type chinook in the Situk River were of sufficient size to tolerate seawater and probably migrated seaward. Similarly, along the Pacific coast of the United States and British Columbia, ocean-type chinook migrate to sea at approximately 70-80 mm FL (Healey 1980; Healey and Groot 1987).

Migration of ocean-type chinook from the Situk River was slightly later (July-August) than in more southerly British Columbia streams (June-July; Healey and Groot 1987) and may vary annually depending upon the severity of winter and spring. In years with a cold winter and late spring, time of emergence and growth may be retarded and time of emigration delayed. The colder winter and spring of 1989 versus 1988 probably accounts for the later start of emigration observed in 1989 (late July) than in 1988 (late June); average monthly air temperature from

[18]Unpubl. data. J. Edgington and J. Lynch, Alaska Dep. Fish and Game, P.O. Box 667, Petersburg, AK 99833.

January through March 1989 was 2.6-6.5°C cooler than during the same period in 1988 (NOAA 1988, 1989). Kissner and Hubartt (1987) also reported a later out-migration of ocean-type chinook in the Situk River in 1985 (August) than in 1984 (July) and attributed the later migration in 1985 to an extremely cold and late spring.

Growth of chinook in the Situk River was similar to that reported in some estuaries. Chinook rearing in the lower Situk River increased from 40 to 80 mm FL from May to early August. In some British Columbia estuaries, chinook fry increased from 40 to 70 mm FL from March to June (Healey 1980; Levy and Northcote 1982). Changes in average length of fish (over time) from the general population probably underestimate the true growth rate because of fish emigration and immigration in study areas (Healey 1991). Actual short-term (late July) growth rate, however, of marked chinook in the lower Situk River (0.57 mm/day) was similar to rates reported for chinook fry in the Campbell River estuary, British Columbia (0.46-0.70 mm/day; Levings et al. 1986), and in Coos Bay, Oregon (0.29-0.54 mm/day; Fisher and Pearcy 1990), but lower than reported by Healey (1980) for fry in the Nanaimo River estuary, British Columbia (1.32 mm/day).

Chinook in the Situk River are capable of migrating to sea at age 0 possibly because of an extended growing season. Peak spawning of chinook in the Situk River occurs the first week of September (Study 1); therefore, based on mean daily water temperature (Fig. H.6), peak emergence of fry (calculated from heating units—900°C days to emergence; Russell et al. 1983) would occur the first week of April. Peak emergence of chinook is in mid- to late April or May in other streams: Big Qualicum River (Lister and Genoe 1970), Sixes River (Reimers 1971), and Taku River (Kissner 1978). Early emergence and a longer growing season probably allow ocean-type chinook in the Situk River to reach the minimum size (60-70 mm) necessary to adapt to seawater as age-0 fish.

Situk River chinook appear to be unique because they have life-history characteristics intermediate between typical stream- and ocean-type populations. Most juvenile chinook out-migrate from the Situk River at age-0, at a size and time very similar to ocean-type populations in the Pacific Northwest. Adult freshwater entry (June-July) and spawning timing (mid-August to mid-September), however, is more similar to stream-type populations than ocean-type[19]. Some advantages of the ocean-type life history compared to the stream-type are lower mortality because of less time rearing in fresh water and quicker availability for recruitment into fisheries.

This study documented for the first time that ocean-type life history dominates a stream population of chinook north of 56°N latitude. Taylor (1990) had previously shown that ocean-type chinook were rare north of British Columbia, Canada. The only other river in Alaska with an apparent emigration of substantial numbers of ocean-type chinook smolts is the Deshka River in Southcentral Alaska (Delaney et al. 1982). In the Situk River, peak emergence of chinook appears to be in early April. Chinook migrate downstream in two phases: 1) a spring dispersion of emergent fry to suitable rearing areas in mid-upper river, and 2) a summer migration of presmolts to the lower river. Juveniles rear in and acclimate to seawater in the lower river for 1-4 weeks (late June and July) before entering the main estuary by early August at about 80 mm FL.

Future tag recoveries of adults returning from juveniles coded-wire tagged in July 1989 should provide valuable information on the ocean distribution, survival, and exploitation rate of this unique stock. In-stream recoveries of adult coded-wire tagged chinook will also substantiate our age designations.

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[19]S. McPherson, Alaska Dep. Fish and Game, Div. Commercial Fish, Southeast Region, 802 Third St., Douglas, AK 99824-0020. Pers. commun., 1992.

Table 4.1—Release and recovery of marked (Panjet and adipose clip) juvenile chinook salmon in the lower and upper Situk River, 1989. (LC = lower caudal Panjet mark; UC = upper caudal Panjet mark; AD = adipose clip).

Date	River location	Total marks released			Marks recaptured		
		LC	UC	AD	LC	UC	AD
6/19-20	upper		720				
6/22	lower	40					
7/7	upper		162			6	
7/8	lower	189			1		
7/16-20	lower			10,191*	64	30	
7/25-26	lower				4		155
7/27	upper					1	
7/31	lower						13
8/1	lower						103
Total		229	882	10,191	69	37	271

*Coded-wire tagged.

Table 4.2—Percent survival of juvenile chinook salmon of similar size from the upper and lower Situk River, June-July 1988, after 96 h in 26-30‰ salinity seawater. Significance based on Chi-square test.

Fork length (mm)	Percent survival: Upper river %	Upper river Sample size	Lower river %	Lower river Sample size	*P*
35-39[a]	0	5		0	
40-49[a]	64	39	100	12	<0.05
50-59[b]	90	10	100	24	NS
≥60[c]	100	15	100	36	NS

[a]Fish from June sampling.

[b]Predominately fish from June sampling.

[c]Predominately fish from July sampling.

Table 4.3—Percent age composition of juvenile chinook salmon measured in the Situk River, 1988-89.

Year	Period	Number aged	Percent	
			Age 0	Age 1
1988	Apr.-Sept.	136	97.8	2.2
1989	May -Sept.	114	98.2	1.8

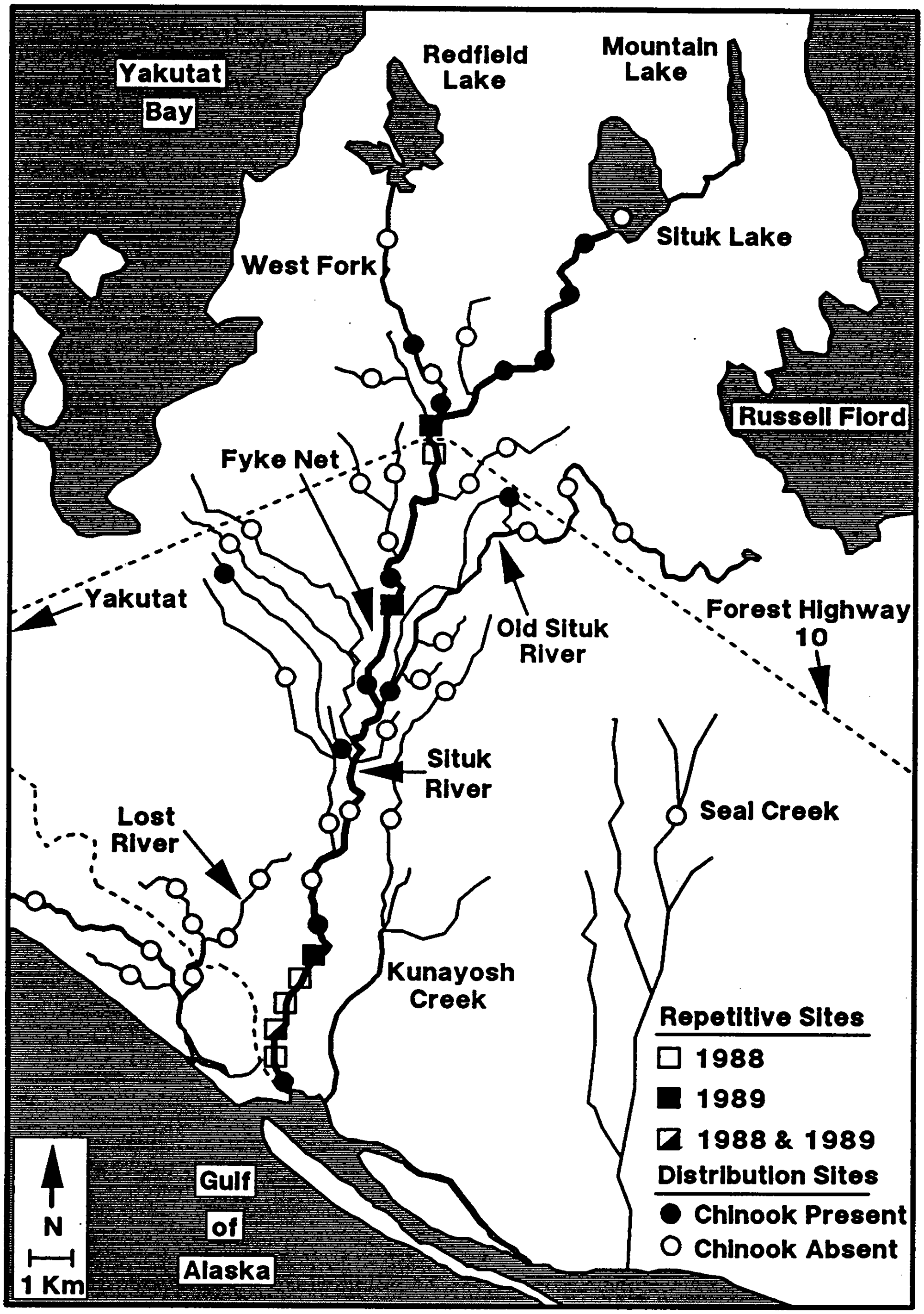

Figure 4.1—Sites sampled for juvenile chinook salmon in the Situk River and neighboring watersheds, 1987-89. Sites were either repetitively sampled in a given year (repetitive sites) or were sampled only once (distribution sites). Chinook were present in all repetitive sites.

Figure 4.2—Tattoo-marking juvenile chinook salmon on caudal fin.

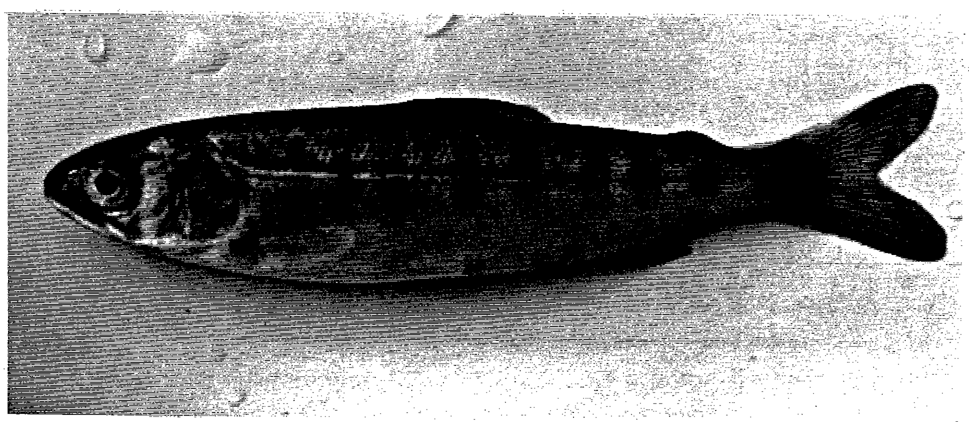

Figure 4.3—Juvenile chinook salmon with tattoo on lower caudal fin.

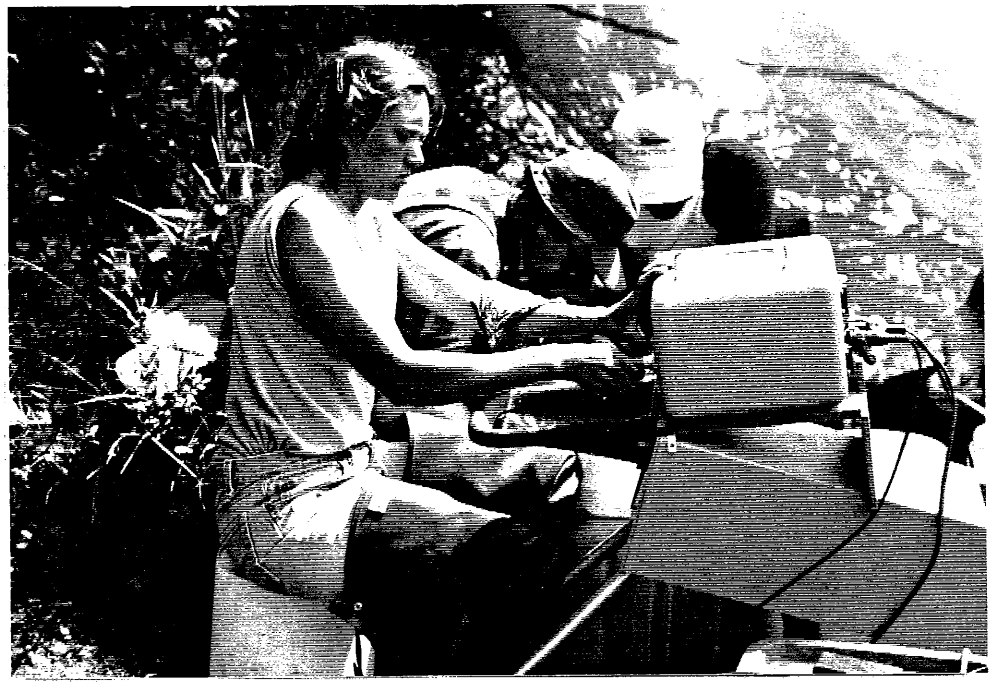

Figure 4.4—Coded-wire tagging juvenile chinook salmon in the lower Situk River, 1989.

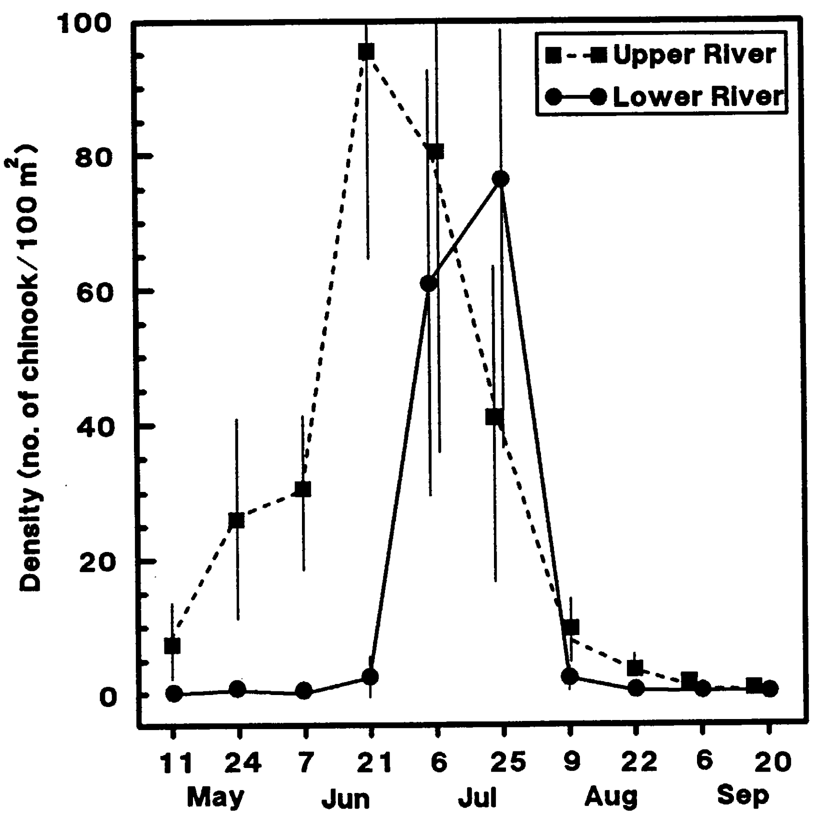

Figure 4.5—Mean density (±SE) of juvenile chinook salmon by sampling period in repetitive sites in the upper and lower Situk River, 1989. For each data point, n = 10 (2 sites x 3 channel edges, 1 willow edge, and 1 debris pool per site).

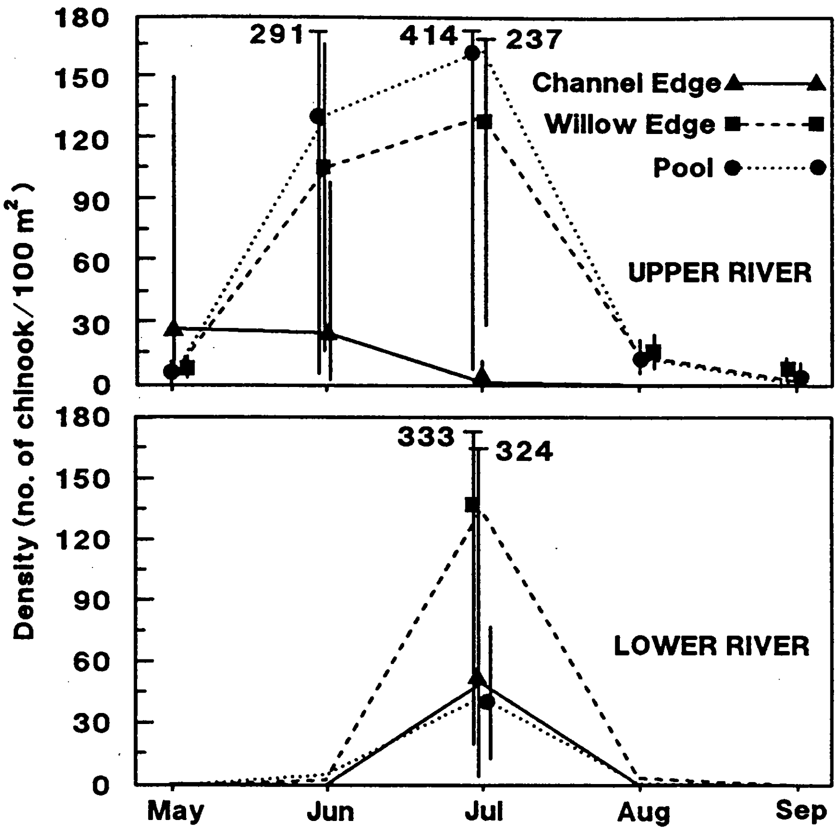

Figure 4.6—Mean density (±range) of juvenile chinook salmon by month and habitat type in repetitive sites in the upper and lower Situk River, 1989. Channel edges, $n = 12$; willow edges, $n = 4$; pools with large woody debris, $n = 4$. (2 sampling periods x 2 sites x 3 channel edges or 1 willow edge or 1 pool per site).

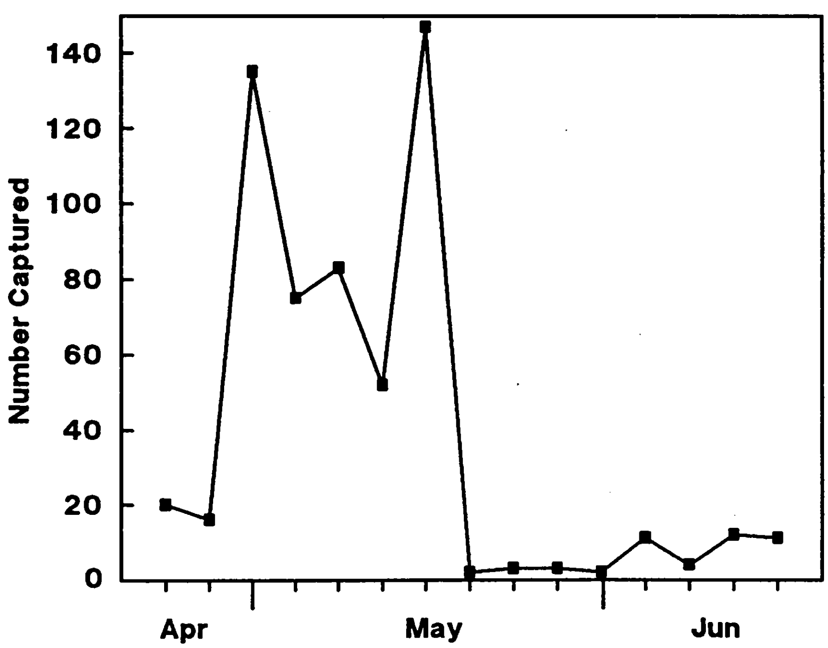

Figure 4.7—Number of juvenile chinook salmon captured by fyke net in the upper Situk River, 1989.

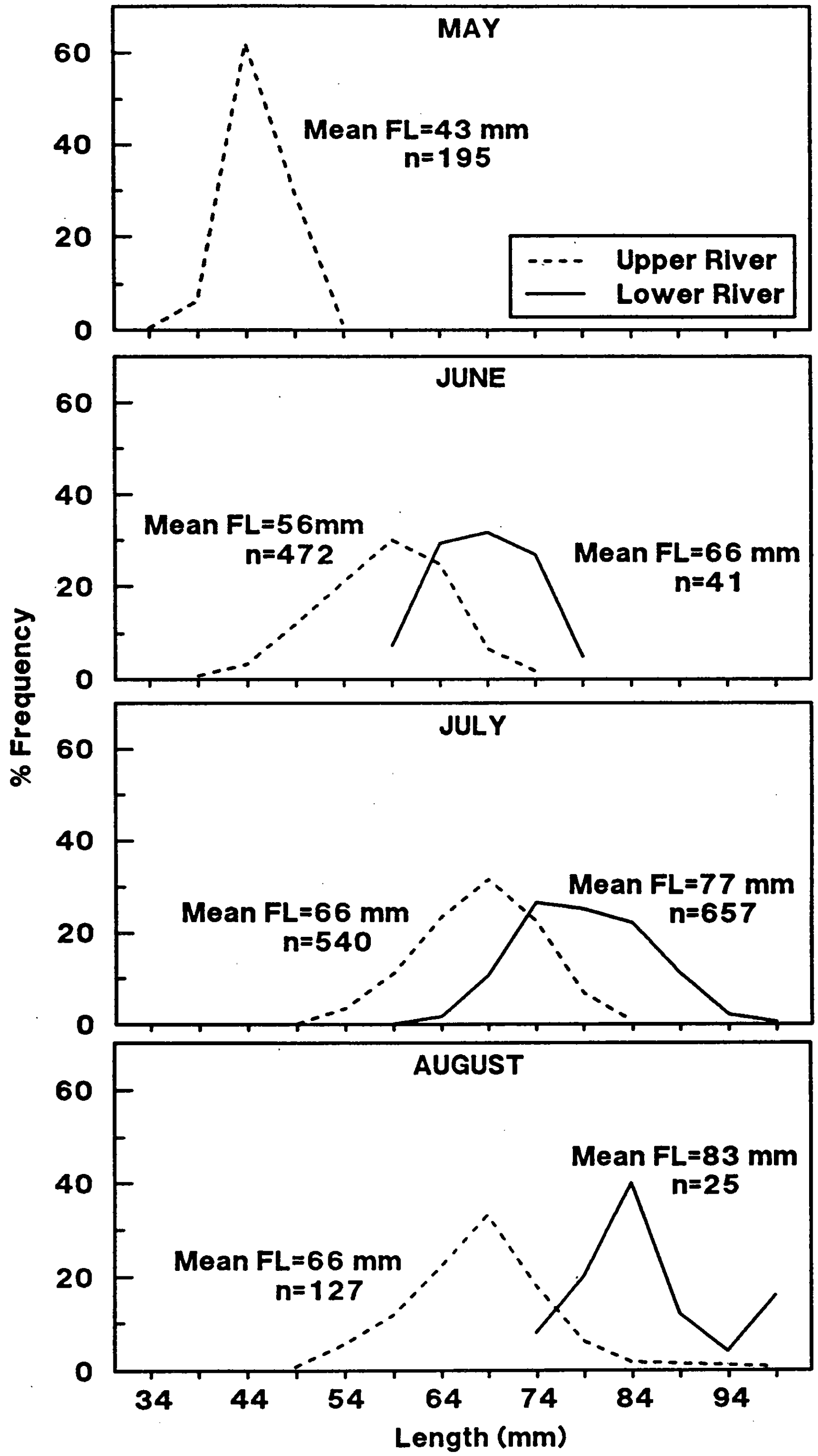

Figure 4.8—Length frequency distributions of juvenile chinook salmon by month in the upper and lower Situk River, 1989. Length frequencies are not shown when <15 chinook were measured. X-axis represents upper limit of 5-mm interval.

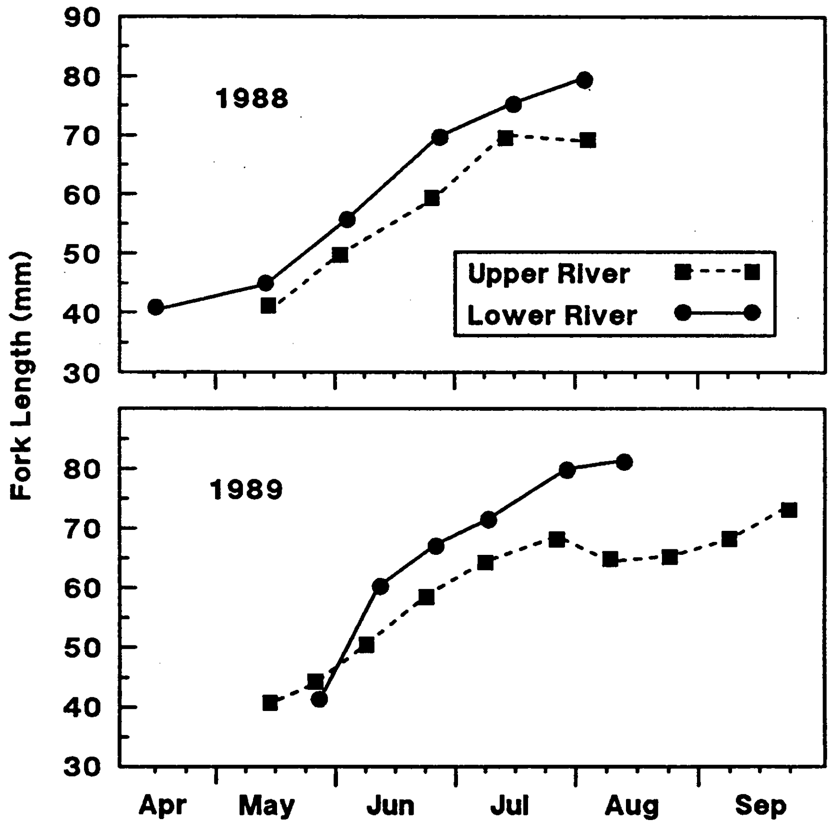

Figure 4.9—Mean fork length of juvenile chinook salmon in the upper and lower Situk River, 1988 and 1989. Each data point represents a minimum of four (range 4-381) fish measured.

STUDY 5.

LIFE-HISTORY OF OCEAN-TYPE SOCKEYE IN THE SITUK RIVER

Rationale

After Hubbard Glacier dams Russell Fiord, water overflowing into the Situk River drainage will flood most habitat used by the endemic ocean-type sockeye. Gaining a better understanding of the life history and habitat of these uncommon fish will allow better assessment of the effects of flooding and informed decisions on restoration.

Objectives

Objectives of this study were to describe migration timing, size at migration, habitat utilization, and salinity tolerance of ocean-type sockeye in the Situk River.

Summary of Results

Eleven sites located from the estuary to Forest Highway 10 were sampled for juvenile sockeye from March to September 1988. Two separate migrations of sockeye fry were apparent: an early migration of newly emerged fry into the estuary in March and April, and a later migration of larger sockeye through the lower river in May and June. Neither group remained long in the estuary or lower river; most early migrants disappeared from their primary habitat (tidal sloughs) by mid-May, and most later migrants spent less than 3 weeks in the lower river and estuary. Size was a determining factor in seaward migration. Fry apparently left rearing areas throughout the river and estuary and moved seaward as their size approached 50 mm, the threshold size for 100% survival in full-strength seawater.

METHODS

Heifetz et al. (1989) sampled the estuary and three upriver sites in Old Situk River in 1987; our 1988 study resampled some of the 1987 estuary sites and added sites in the lower and upper river to obtain a fuller picture of the migration of ocean-type sockeye (Fig. 5.1). Ocean-type sockeye abundance and distribution data from Heifetz et al. (1989) are also included in Study 8.

Sampling sites were established in the Situk estuary, lower Situk River, upper main-stem Situk River, and Old Situk River. In the estuary, five sites were established in two habitat types: two "tidal sloughs" in the intertidal *Carex* marshes and three "estuary beaches" in the estuary basin (Fig. 8.1). In the lower river, four sites were located between the boat landing and the upstream limit of tides; in the upper river, one site was in the main stem about 100 m upstream of Forest Highway 10, and one site was in Old Situk River 30 m upstream of Forest Highway 10 (Fig. H.4). All sites were sampled for juvenile sockeye about every 3 weeks from 13 March to 1 September 1988.

To show relative changes in sockeye abundance, we indexed fish numbers by catch per unit effort and report total numbers caught each sampling period. Sampling methods differed among habitat types. At each beach site in the estuary, three separate areas 20-50 m apart were sampled with a seine that was 28 m long and 3 m deep, with wings of 13-mm mesh and a central bag of 6-mm mesh. The seine was set parallel to and 40 m from shore with a skiff and retrieved with ropes from shore. In tidal sloughs and in riverine sites, a 30-m section was repeatedly seined (≥3 times) with a pole seine (Fig. 5.2). At sites in the lower river, minnow traps were also fished, but were ineffective on sockeye (Study 2). In all sampling periods, the same areas were seined the same number of times so that effort was approximately constant.

Salmonids caught were tranquilized with dilute MS-222, identified, and measured for FL. Scale samples were taken from a size range of sockeye to determine age. To assess residence time, juvenile salmonids in all sites in the lower river and in one tidal slough were marked externally with fluorescent pigment sprayed on with compressed air; pigment colors were changed each sampling period. All captured salmonids were examined for marks under an ultraviolet lamp inside a darkened box.

Salinity tolerance tests were used by Heifetz et al. (1989) to determine the ability of sockeye fry to survive in seawater. For convenience, we include their results in this report. In May and June 1987, Heifetz et al. (1989) collected sockeye from tidal sloughs and placed them in 60-L plastic containers filled with aerated water at 0, 26, 28, or 30‰ salinity at ambient temperature (mean 10.0°C in May and 9.1°C in June). Ocean water was mixed with either fresh water or Instant Ocean[1] salts to obtain desired salinity. To avoid crowding, no more than 15 fish were placed in each container. Mortalities were removed and measured every 12 h.

RESULTS

Sockeye fry migrated in two phases (Table 5.1; Fig. 5.3). The first phase was an early migration of newly emerged fry into the estuary in March and April. Newly emerged fry (31-32 mm mean FL) were already present in large numbers in tidal sloughs when sampling began in March. These fish reached peak abundance in tidal sloughs in mid-April and most were gone by mid-May. Only small numbers were caught in estuary beaches. The second phase was a later migration of larger sockeye fry (40-50 mm mean FL) that moved through the lower river in large numbers in May and June. Their movement into the lower river roughly coincided with a decline in fry numbers in upper river areas (Table 5.1). In Old Situk River, fry numbers peaked in mid-June and declined sharply thereafter; in the upper main-stem, only small numbers of sockeye fry were caught after mid-May. Few sockeye fry were caught in the estuary from mid-June to September, indicating that during the second phase of the migration, sockeye were distributed in open water and migrated through the estuary without extended rearing.

Size of sockeye differed between the estuary, lower river, and upper river areas (Table 5.2; Fig. 5.4). In tidal sloughs, mean FL increased sharply between mid-April and late May, then remained at 47-49 mm thereafter. Mean FL also increased sharply in the lower river between mid-May and late June, but it remained at 50-56 mm thereafter. Thus, the asymptotic size was about 5 mm smaller in tidal sloughs than in the lower river. In upper river areas, sockeye FL averaged between 32 and 39 mm all sampling periods, and never exceeded 50 mm, indicating continuous emergence of fry throughout the study and emigration when fry reached about 50 mm.

Recaptures of spray-marked sockeye fry indicated they remained less than 3 weeks in the lower river, which was similar to chinook and age-1 sockeye smolts but shorter than coho fry (Table 5.3). A total of 5,634 sockeye fry were marked in the lower river; only 0.3% were recaptured. Similarly, only 0.2% of nearly 1,200 marked chinook and age-1 sockeye smolts were recaptured. In contrast, 3% of coho fry were recaptured, significantly ($P < 0.001$; Chi-square test) more than the other species. No marked fish was recaptured in an area different from its marking site. Too few fish were marked and recaptured in tidal sloughs to estimate residence time. Of 141 sockeye fry marked in the tidal slough, 2 were recaptured.

In the salinity tolerance tests conducted by Heifetz (1989), survival of sockeye fry was directly related to fish size (Fig. 5.5). Survival in 30‰ salinity was 30% for 30-39 mm FL, 67% for 40-49 mm FL, and 100% for 50-59 mm FL. About two-thirds of the mortalities occurred within 24 h, and all fish in fresh water survived. Thus, a threshold size of at least 50 mm was required for 100% survival in seawater.

DISCUSSION

Two life-history patterns of ocean-type sockeye were evident in the Situk River and estuary. One pattern was characterized by an early migration to the estuary of newly emerged fry where they reared in tidal sloughs to the threshold size of about 50 mm before migrating to sea by mid-May. The second pattern involved a later migration of larger fry (>50 mm mean FL) that had apparently reared in upper river areas before migrating downstream in May and June. These larger fry reared less than 3 weeks in the lower river and migrated directly through the estuary without using tidal sloughs.

In other studies (Study 6 and 7), two modes were also evident in the migration of sockeye fry. Large numbers of sockeye fry migrated from Old Situk River during two periods, with modes in April and June (Study 6). Smaller numbers of sockeye fry also migrated downstream from the lower main-stem Situk River during these same two periods (Study 7).

The asymptotic size of about 45-55 mm for sockeye fry in tidal sloughs and the lower river indicates that fish went to sea when they could survive in seawater. The slightly smaller asymptotic size in tidal sloughs compared to the lower river may indicate that rearing in brackish water allowed fry to acclimate to seawater at a smaller size.

The two life-history patterns may indicate the presence of more than one ocean-type stock of sockeye in the Situk River: one migrating seaward early and using estuarine wetlands for rearing, the other migrating later and using fresh water, upriver habitat for rearing. The early migrating fry could also originate from stocks in other streams that share the Situk estuary, such as the Ahrnklin River, or from a combination of stocks from the Situk and other rivers. Based on trapping of downstream migrants (Study 6), the larger sockeye fry in the lower river in mid-summer were mainly from the Situk and Old Situk Rivers.

Conversely, the two life-history patterns could be exhibited by a single stock that spawns in a variety of habitat conditions, or produces fry that emerge over an extended period. The early migration to the estuary by newly emerged fry could be involuntary; fry could be swept downstream from certain spawning areas where suitable pool habitat is not available for rearing. Fry emerging during spring freshets may also be swept downstream, whereas fry emerging between freshets may be able to maintain position. More research is needed to determine whether the two life-history patterns observed in this study represent two genetically different ocean-type stocks in the Situk River.

Tidal sloughs appear to be critical habitats for sockeye fry that migrate into the Situk estuary in March and April. The south-facing aspect and exposure to sunlight of tidal sloughs in the estuary cause them to warm up earlier in spring than freshwater habitats in the river (Study 8). The brackish water in tidal sloughs also may allow sockeye fry to acclimate to seawater at a smaller size than sockeye rearing in fresh water. Although we did not measure food abundance, prey are probably abundant during flood tides. The combined effects of warm, brackish water and abundant prey allow sockeye fry in tidal sloughs to grow large enough to migrate to sea by mid-May.

Marine survival of the two different life-history patterns of ocean-type sockeye may differ because they enter the ocean at different seasons. The estuary-rearing sockeye enter the ocean about 1 month before both the river-rearing ocean-type sockeye and the lake-rearing age-1 sockeye. The estuary-rearing sockeye have a timing of ocean entry more like pink and chum salmon than other sockeye. Research is needed to determine marine survival of both life-history patterns of ocean-type sockeye and whether earlier entry into the ocean is advantageous.

Table 5.1—Total catch of sockeye fry in different areas of the Situk River, Old Situk River, and estuary, March-September 1988. A dash indicates the area was not sampled.

Date	Tidal slough	Estuary beach	Lower river	Upper Situk	Old Situk
March 13-15	1,101	40	—	—	—
April 11-15	2,015	33	674	—	—
May 11-15	70	—	1,836	82	—
June 1-3	112	0	2,836	3	230
June 20-24	23	4	892	3	561
July 12-15	5	3	71	6	65
August 2-5	0	0	35	3	7
August 30-September 1	0	—	6	—	6

Table 5.2—Mean fork length (mm) of sockeye fry in different areas of the Situk River, Old Situk River, and estuary, March-September 1988. Range is in parentheses. A dash indicates that no sockeye were captured or the area was not sampled.

Date	Tidal slough	Estuary beach	Lower Situk	Upper Situk	Old Situk
March 13-15	32 (29-57)	31 (29-32)	—	—	—
April 11-15	32 (25-46	31 (28-33)	31 (29-55)	—	—
May 11-15	39 (31-52)	—	33 (28-66)	33 (29-50)	—
June 1-3	48 (31-69)	—	40 (29-55)	32 (28-34)	35 (29-49)
June 20-24	49 (31-58)	57 (48-65)	50 (34-63)	33 (32-34)	34 (27-45)
July 12-15	47 (43-55)	61 (60-63)	53 (40-70)	39 (37-42)	34 (27-47)
August 2-5	—	—	51 (38-63)	39 (37-43)	38 (32-49)
Aug. 30-Sept. 1	—	—	56 (50-66)	—	40 (32-48)

Table 5.3—Number of fish marked with fluorescent pigment in a tidal slough in the Situk estuary and in the lower Situk River, 13 May to 5 August 1988. The number of marked fish recaptured in subsequent sampling periods is in parentheses.

Location	Sockeye		Coho		Chinook
	Fry	Smolt	Fry	Smolt	smolt
Lower Situk	5,634 (16)	596 (1)	4,415 (130)	111 (0)	595 (0)
Tidal slough	141 (2)	5 (0)	164 (2)	4 (1)	0

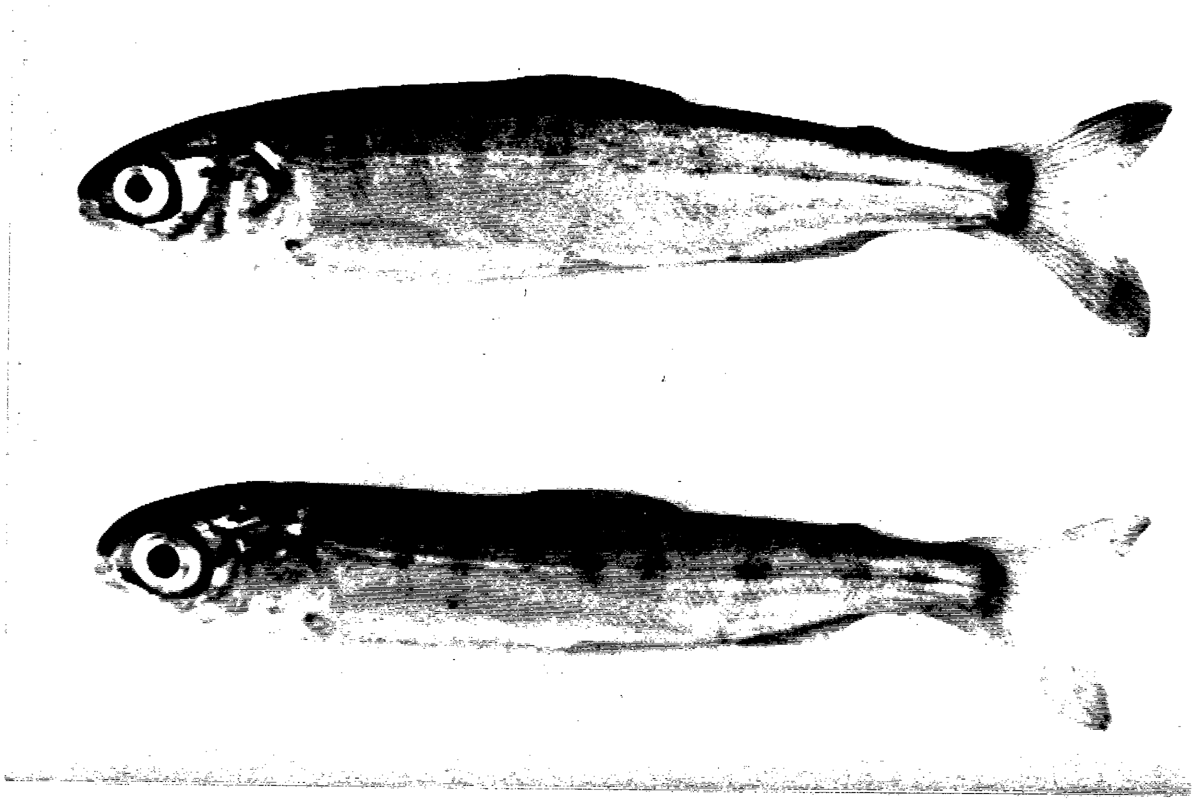

Figure 5.1—Ocean-type sockeye (top) and a 1-year-old lake-type sockeye smolt (bottom).

Figure 5.2—Sampling with a pole seine in a tidal slough, Situk estuary, May 1988.

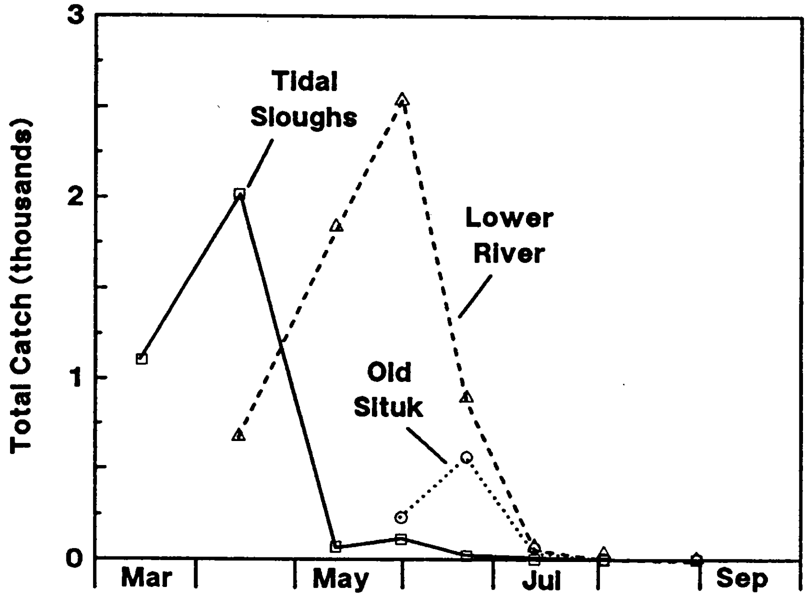

Figure 5.3—Catch of sockeye fry in the lower Situk River, tidal sloughs in the Situk estuary, and pools in Old Situk River, March-September 1988.

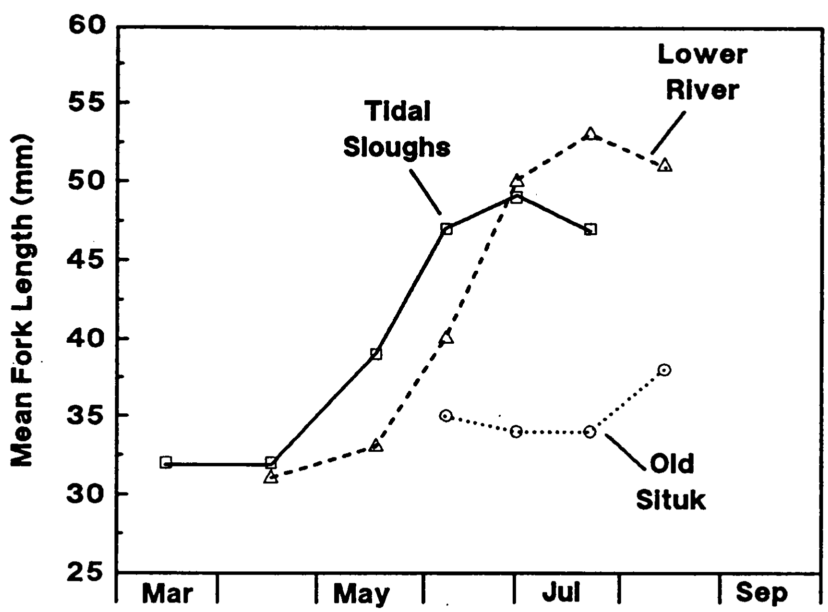

Figure 5.4—Mean fork length of sockeye fry in the lower Situk River, tidal sloughs in the Situk estuary, and pools in Old Situk River, March-September 1988.

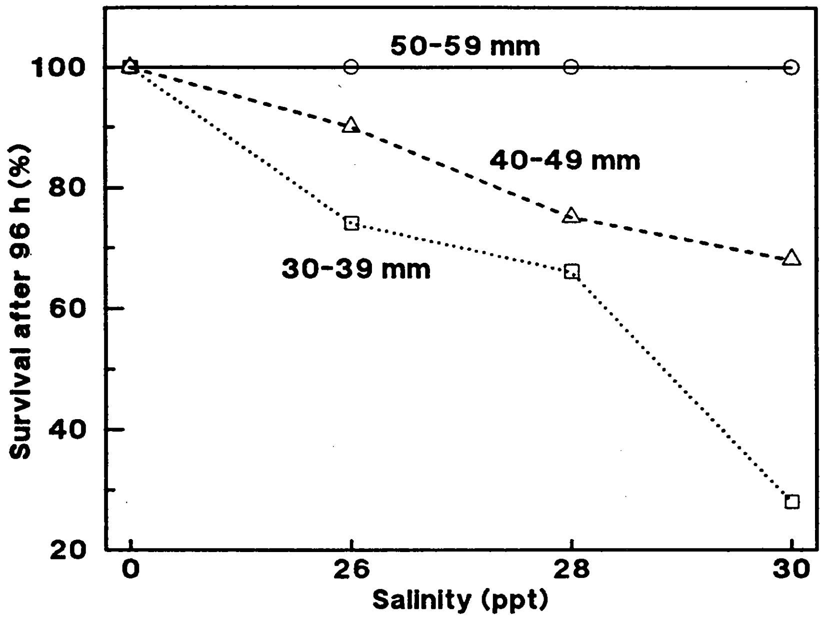

Figure 5.5—Percent survival of three size groups of sockeye fry from the Situk estuary after 96 h in 0, 26, 28, and 30‰ salinity. Data are from Heifetz et al. (1989).

STUDY 6.

DOWNSTREAM MIGRATION OF JUVENILE SALMONIDS IN OLD SITUK RIVER

Rationale

The yield of juvenile salmonids from Old Situk River provides a direct measure of potential impacts of flooding on salmonid production from Old Situk River.

Objectives

Objectives of this study were to enumerate juvenile salmonids emigrating from Old Situk River and to evaluate the importance of Old Situk River as winter habitat for juvenile salmonids.

Summary of Results

Juvenile salmonids were captured at a weir on Old Situk River from 14 April to 2 July 1989 to evaluate smolt yield and winter habitat. An estimated 26,200 coho, 7,000 sockeye, 500 steelhead, and 5 chinook smolts migrated from Old Situk River. An estimated 93,000 age-1 coho parr emigrated from Old Situk River and probably reared in the main-stem Situk River until smoltification. The yield of parr and smolts (45/100 m^2) indicates that Old Situk River is important winter habitat. The results of this study have been previously reported by Thedinga et al. (1991).

METHODS

A V-shaped weir was constructed across Old Situk River approximately 200 m upstream from its confluence with the Situk River (Figs. 6.1, 6.2). Two 1.5 m^2 fyke nets, each 3.8 m long, were fished from the apex of the weir from 14 April to 2 July 1989. The weir was constructed of 6-mm^2 mesh Vexar supported by 5.1-cm x 10.2-cm lumber secured by hose clamps to 3.2 cm diameter x 244 cm long steel pipe pounded partway into the substrate. Each fyke net was connected to a floating live box by a 10 cm diameter flexible hose. Fyke nets were fished 24 hours every day except for 2 days in May during a major freshet and for short daylight periods to allow passage of adult steelhead in mid-May and sockeye salmon in June.

Parr and smolts of all species and chinook fry were enumerated daily; fry of other species were enumerated every other day. All chinook fry and a subsample of up to 100 parr and 100 smolts of each species were measured for FL daily. Every other day a subsample of 30 fry of each species (except chinook salmon) were measured, and scale samples were taken from each subsampled species except Dolly Varden. Subsamples of 30 parr and 30 smolts of each species were also weighed.

Body size and external characteristics of the salmonids were used to identify and separate fry, parr, and smolts. For some species, especially coho salmon, it was sometimes difficult to separate fast-growing fry from slow-growing parr. Therefore, we set a size criterion to separate fry and parr (e.g., coho salmon ≤45 mm were classified as fry). An RBase computer program was later used to proportion the number of fry, parr, and smolts based on length frequency and ageing data.

To test the effectiveness of the fyke nets in capturing fish (trap efficiency), 45-50 coho smolts were marked by a fin clip and released approximately 200 m upstream of the weir on six different sampling periods in May and June. Four distinctive caudal fin clips were used; upper and lower tips were alternately clipped the first four marking periods followed by upper and lower v-notches the last two periods. The recapture rate of marked coho smolts caught in the fyke nets was used to estimate the percentage of all smolts captured. All recaptured smolts were combined for calculating trap efficiency because not all fish with a specific fin clip were recaptured before that clip was used again.

Trap efficiency ($\hat{E}$) was estimated by dividing the number of recaptured marked smolts by the number of marked smolts released upstream:

$$\hat{E} = R/M \,, \tag{1}$$

where R is the number of marked fish recaptured and M is the number of marked fish released upstream. Numbers of coho smolts were estimated by dividing the number of coho smolts caught by estimated trap efficiency:

$$\hat{N} = C/\hat{E} \,, \tag{2}$$

where $\hat{E}$ is the estimated number of unmarked coho smolts migrating past the fyke nets and C is the total number of unmarked smolts in the catch. The confidence interval for $\hat{E}$ was determined by the bootstrap method (Efron and Tibshirani 1986) by resampling R from the binomial distribution ($M, \hat{E}$) and C from the binomial distribution ($\hat{N}, \hat{E}$). The percentile method was used to compute the confidence interval based on 200 bootstrap replications.

Water temperature was recorded hourly with a thermograph, and stream stage was recorded daily with a staff gauge. Rearing area of Old Situk River was calculated by multiplying its mean width (Study 2) by its total length (determined from a U.S. Geological Survey (USGS) topographical map).

RESULTS

The results of this study have been previously reported by Thedinga et al. (1991).

Over 110,000 juvenile salmonids were captured in the fyke nets in Old Situk River; 42% were fry, 45% were parr, and 13% were smolts (Table 6.1). Coho smolts were the most abundant fish, making up about 70% of the catch, and chinook and Dolly Varden smolts were the least abundant (≤0.1%).

A total of 123 of 293 (42%) coho smolts marked and released upstream of the weir were recaptured at the weir (Table 6.2). A total of 26,206 (95% confidence interval, 22,939-30,059) coho smolts were estimated to have migrated from Old Situk River (Table 6.3). If trap efficiency (42%) calculated for coho smolts is applied to other species captured at the weir, estimates of total numbers of fish increase by a factor of 100/42 or 2.4. Marked smolts returned slowly to the weir—some fish were not recaptured until 20 days after release, and fish were still being recaptured just 3 days before weir removal. Approximately 9 and 22% of marked smolts released upstream of the weir were recaptured at the weir within 1 and 2 weeks, respectively.

Based on the actual number of fish captured at the weir and the estimated rearing area of Old Situk River (288,559 m^2), the total yield of salmonids ($\geq$age 1) was 19 fish/100 m^2 (Table 6.3). When the expanded number of fish based on trap efficiency was used, total yield became about 45 fish/100 m^2 (Table 6.3). Coho parr and smolts accounted for 91% of the actual total yield; parr made up 78% of the coho salmon yield. The yield of salmonid smolts was dominated by coho salmon (79%) while sockeye smolts accounted for 19%. The estimated number of chinook salmon wintering in Old Situk River was low (yield <0.1 smolt/100 m^2).

Migration timing varied by life stage within and between species (Table 6.1). Peak migration of coho parr occurred earlier (April) than coho fry or smolts (June) (Fig. 6.3). Sockeye fry migration had a small peak in April and a larger peak in June when most (96%) fry migrated; the sockeye smolt migration peaked in both April and June (Fig. 6.4). Sockeye smolts were approximately 10 mm larger (mean FL) during the peak migration in June when compared to fish migrating in April (Fig. 6.5). Nearly all pink (99%) and chum (91%) fry migrated in April and May, whereas most chinook fry (86%) migrated in June (Fig. 6.6). Steelhead and Dolly Varden parr had no obvious migration peak, whereas steelhead smolts had peaks in April and May and Dolly Varden smolts had a peak in May (Fig. 6.7).

Daily mean FL of all juveniles except coho fry, steelhead parr, and sockeye, steelhead, and Dolly Varden smolts increased steadily throughout the study (Figs. 6.5, 6.8-6.11). Mean FL of coho fry decreased from April through May because of an early emigration of large fry (mean FL 44 mm); however, FL of fry increased sharply in June (Fig. 6.8). Mean FL of sockeye smolts increased until mid-June and then decreased until early July (Fig. 6.5). In April and May, when most pink and chum fry migrated, mean FL was 34 and 39 mm, respectively (Fig. 6.9). In June, mean FL increased to 49 and 59 mm for pink and chum salmon fry, respectively. From April through June, the daily mean FL of chinook fry increased from 40 mm to almost 70 mm (Fig. 6.9). The largest steelhead parr and smolts migrated in June (Fig. 6.10), whereas the largest Dolly Varden parr migrated in late June and the largest smolts migrated in May (Fig. 6.11). Overall mean FL and weight of each species by age is summarized in Table 6.4.

Age composition varied among species captured (Table 6.5). For coho salmon and steelhead, age-1 fish were the most abundant (56 and 77%, respectively), whereas ocean-type fish dominated catches of sockeye and chinook salmon (70.3 and 99.8%, respectively). Among smolts, most coho and sockeye salmon were age 1, whereas most steelhead were age 3 (95, 99, and 47%, respectively) (Table 6.6).

Daily mean water temperature increased from 5 to 12°C during the study (Fig. 6.12), and stream stage varied from approximately 40 cm to nearly 80 cm; however, most variation in stream stage resulted from a freshet on 14 May when water depth rose 32 cm. Excluding the freshet, stream stage ranged from only 38 to 50 cm. Peaks in the migrations of coho fry and smolts, sockeye smolts, chinook fry, and steelhead parr corresponded to the sharp increase in water depth in early June (Figs. 6.3, 6.4, 6.6, 6.7). The rapid increase in water temperature at the end of April corresponded to peaks in the migrations of coho parr, sockeye fry, pink fry, and steelhead smolts (Figs. 6.3, 6.4, 6.6, 6.7).

DISCUSSION

The expanded estimate of juveniles based on trap efficiency probably overestimates the actual number of fish that migrated from Old Situk River. Marked smolts released upstream of the weir were probably more susceptible than other fish to predation or delays in their migration because of handling stress. Old Situk River has relatively little large woody debris; therefore, pools and cover are limited, and predation, especially just above the weir where smolts tended to accumulate, may have been higher than in other areas of the river or main stem. Smolts could also have passed through the weir during the day when the fyke nets were opened to allow passage of adult steelhead and sockeye salmon. Undoubtedly, by the end of the study all marked smolts had not migrated from Old Situk River because one marked smolt was recaptured just 3 days before removal of the weir.

Mean length of coho fry (44 mm FL) was unusually large in Old Situk River in April. Adult coho salmon in the Situk have an extensive spawning period beginning in September and extending into winter. This probably results in a wide range in emergence timing and, hence, a wide range in fry size. Because Old Situk River is spring fed, extremes in water temperature are less pronounced, and overall annual fluctuations in temperature are less severe than those observed in lake or runoff-fed streams. The large size of coho fry in late April compared to May indicates that these fish may have been the progeny of early spawning adults with eggs that were incubated in relatively warm spring water, resulting in early emergence and fast-growing fry. The other extreme (late spawning adults and late emerging fry) could result in very small fry by winter. These small fry may not form an annulus and the next spring could be mistaken for large fry when they are actually age-1 parr.

The proportions of age-1 coho (95%) and sockeye (99%) smolts in Old Situk River differ from those found in other Alaskan streams, whereas age composition for steelhead smolts is similar. For coho salmon, Crone and Bond (1976) and Thedinga and Koski (1984) reported that age-1 smolts comprised only 20 and 27% of the smolt population in two Southeast Alaskan streams. The proportion of freshwater age-1 coho adults caught in the Situk River commercial fishery was approximately 50% (Riffe et al. 1987). Age composition of coho salmon in Old Situk River is typical of the more southerly streams of the Pacific Northwest where nearly all coho smolts are age 1 (Shapovalov and Taft 1954; Niska and Willis 1963). For sockeye salmon, most rear for 1-2 years in lakes (Foerster 1968). The proportion of freshwater age-1 sockeye adults captured in the Situk River commercial fishery (67%) (Riffe et al. 1987) was much lower than the proportion of age-1 sockeye smolts (99%) found in Old Situk River. The sockeye fry that emigrated from Old Situk River are probably "ocean type" and the smolts are probably "river type" (Wood et al. 1987) sockeye that rear in river habitats one or more years (Wood et al. 1987; Heifetz et al. 1989). The river-type sockeye smolts from Old Situk River are typical of river-type sockeye salmon found in glacial systems such as the Taku and Stikine Rivers (Wood et al. 1987; Murphy et al. 1989). The high proportion of age-1 coho and sockeye smolts is probably a result of a water temperature regime that is conducive to early emergence and rapid growth. For steelhead in Old Situk River, age-3 smolts were most abundant, followed by age-2 and -4 smolts; this pattern is similar to that found in other Southeast Alaskan streams (Jones 1977).

Yield of juvenile salmonids from Old Situk River indicates that it is an important wintering area for several salmonid species. Based on trap efficiency computations, the yield of coho smolts in Old Situk River (9.1 smolts/100 m^2) was similar to Sashin Creek, Alaska (mean 9.7 smolts/100 m^2) (Crone and Bond 1976), but less than Porcupine Creek, Alaska (mean 29 smolts/100 m^2) (Thedinga and Koski 1984). The large migration of coho parr suggests that after wintering in Old Situk River, parr move to the main stem to rear and probably emigrate as smolts. If coho parr that migrated from Old Situk River became smolts that year, then coho smolt yield (based on actual count) would increase from 4 smolts/100 to 17.3 smolts/100 m^2 and would be similar to the estimates of Thedinga and Koski (1984). If the expanded number of coho smolts and parr are combined, then the estimated yield of 41.3 smolts/100 m^2 would be similar to the mean yield of 42 smolts/100 m^2 reported by Chapman (1965) for three Oregon streams.

Although wintering of sockeye salmon in non-lake habitats is uncommon, age-1 sockeye salmon were the second most abundant group of smolts enumerated from Old Situk River. Thedinga et al. (1988) suggested that sockeye salmon wintered in side sloughs and tributary beaver ponds of the Taku River, Alaska, but little is known about where they actually winter. About one-half of Old Situk River consists of "slough" habitat; that is, areas that are usually braided channel segments that have placid flows and are controlled by shallow groundwater. These areas are probably used by sockeye for wintering before emigrating as smolts. Adult sockeye salmon sampled from Old Situk River were predominately ocean-type (94%), based on scale analysis[20]. Murphy et al. (1988) reported similar timing in the migration of ocean-type sockeye smolts in the Taku River.

Old Situk River provides important habitat for several salmon species. More than 100,000 coho parr and smolts winter in Old Situk Creek. Few sockeye smolts are produced in Old Situk Creek, but many of the uncommon ocean-type sockeye originate there.

[20]Unpubl. data. Alaska Dep. Fish and Game. Commercial Fisheries Div. Scale Laboratory, Douglas, AK 99824. 1990.

Table 6.1—Number, peak migration period, and peak daily count of juvenile salmonids captured at Old Situk River weir, 14 April-2 July 1989.

Species	Stage	Number of fish	Peak migration period	Peak count
Coho	Fry	38,733[a]	June 2-5	1,832
Coho	Parr	39,038	April 18-30	2,854
Coho	Smolt	11,001	May 29-June 9	880
Sockeye	Fry	6,144	June 10-24	620
Sockeye	Smolt	2,578	April 17-25, June 2-5	218
Chinook	Fry	1,265	June 7-25	87
Chinook	Smolt	2	April 18-21	1
Pink	Fry	29,370[a]	April 24-May 7	2,066
Chum	Fry	142	May 5-31	22
Steelhead	Parr	2,020	April 18-June 20	80
Steelhead	Smolt	193	April 18-May 8	24
Dolly Varden	Parr	8,897	April 18-June 26	459
Dolly Varden	Smolt	97	May 14-18	23
Total		139,480[b]		

[a]Coho and pink fry were only counted every other day. On days when fry were not counted, number of fry were estimated by averaging the counts for days before and after the missing day.

[b]Actual number of fish captured was 110,022; see coho and pink fry estimates.

Table 6.2—Number of coho smolts fin clipped and released above Old Situk River weir and recaptured at the weir, 1989.

Release date	Number fin clipped	Fin clip	Number recaptured
May 13, 24	50, 49	Upper caudal	50*
May 19, June 1	50, 50	Lower caudal	32*
June 9	45	Upper caudal notch	23
June 16	49	Lower caudal notch	18
Total	293		123

*Date of release of some recaptured fish was undetermined because the same mark was used twice during the sampling season.

Table 6.3—Yield of juvenile salmonids captured at Old Situk River weir and expanded number of juveniles based on trap efficiency (42%). Rearing area of Old Situk River is 288,559 m^2.

Species and stage	Actual		Expanded	
	Number of fish	Yield (no./100 m^2)	Number of fish	Yield (no./100 m^2)
Coho smolt	11,001	3.8	26,206	9.1
Coho parr	39,038	13.5	92,993	32.2
Sockeye smolt	2,578	0.9	6,141	2.1
Steelhead parr	2,020	0.7	4,812	1.7
Steelhead smolt	193	0.1	460	0.2
Chinook smolt	2	<0.1	5	<0.1
Total	54,832	19.0	130,617	45.3

Table 6.4—Mean length and weight of juveniles captured at Old Situk River weir, 14 April-2 July 1989. A dash indicates that fish were not weighed.

Species	Age (years)	Fork length (mm)	SD	Weight (g)	SD
Coho	0	46	8	1.6	0.5
Coho	1	69	14	4.0	2.5
Coho	2	105	10	13.7	3.7
Coho	3	153	0	34.3	0
Sockeye	0	46	6	1.2	1.2
Sockeye	1	62	6	2.5	0.9
Sockeye	2	94	4	6.9	1.4
Chinook	0	56	7	2.3	0.8
Chinook	1	84	5	—	—
Pink	0	34	1	0.3	0.1
Chum	0	39	3	0.5	0
Steelhead	1	63	9	3.0	1.4
Steelhead	2	91	11	9.0	4.0
Steelhead	3	124	14	21.2	6.0
Steelhead	4	157	11	34.9	7.4
Dolly Varden	[a]	66	13	2.8	5.0
Dolly Varden	[b]	155	30	32.2	0

[a]Parr not aged.

[b]Smolt not aged.

Table 6.5—Age composition of juvenile salmonids caught at Old Situk River weir, 14 April-2 July 1989, extrapolated from number of fish aged.

Species	Number of fish aged	Age in years (%) 0	1	2	3	4
Coho	276	43.3	56.0	0.7	<0.1	0.0
Sockeye	126	70.3	29.5	0.2	0.0	0.0
Chinook	44	99.8	0.2	0.0	0.0	0.0
Steelhead	152	0.0	77.7	14.7	5.4	2.2

Table 6.6—Age composition of smolts captured at Old Situk River weir, 14 April-2 July 1989, extrapolated from number of fish aged.

Species	Number of fish aged	Age in years (%) 1	2	3	4
Coho	61	94.6	5.4	<0.1	0.0
Sockeye	84	99.3	0.7	0.0	0.0
Steelhead	152	0.0	29.8	47.1	23.1

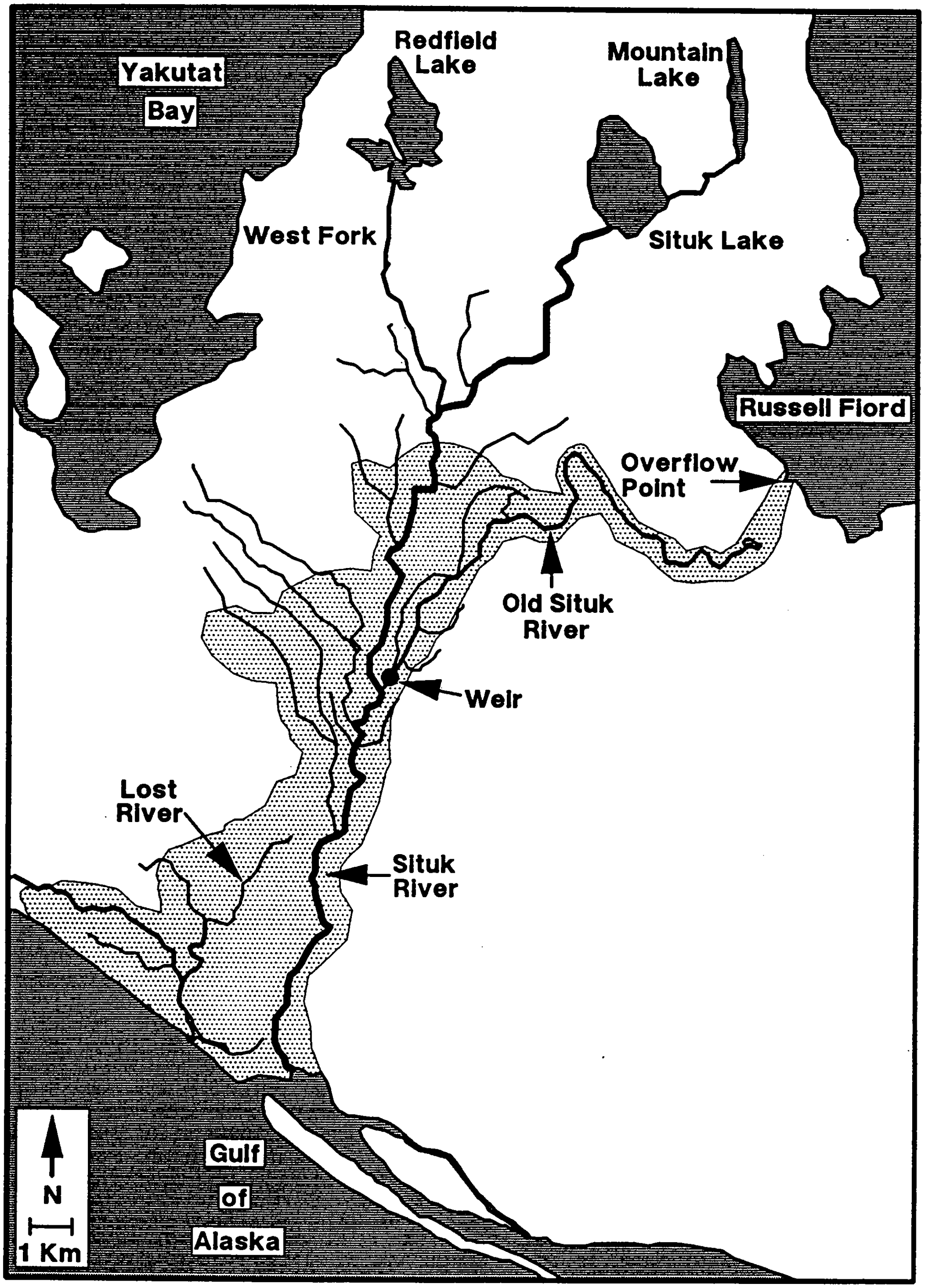

Figure 6.1—Location of weir on Old Situk River. Stippled area is predicted flood zone.

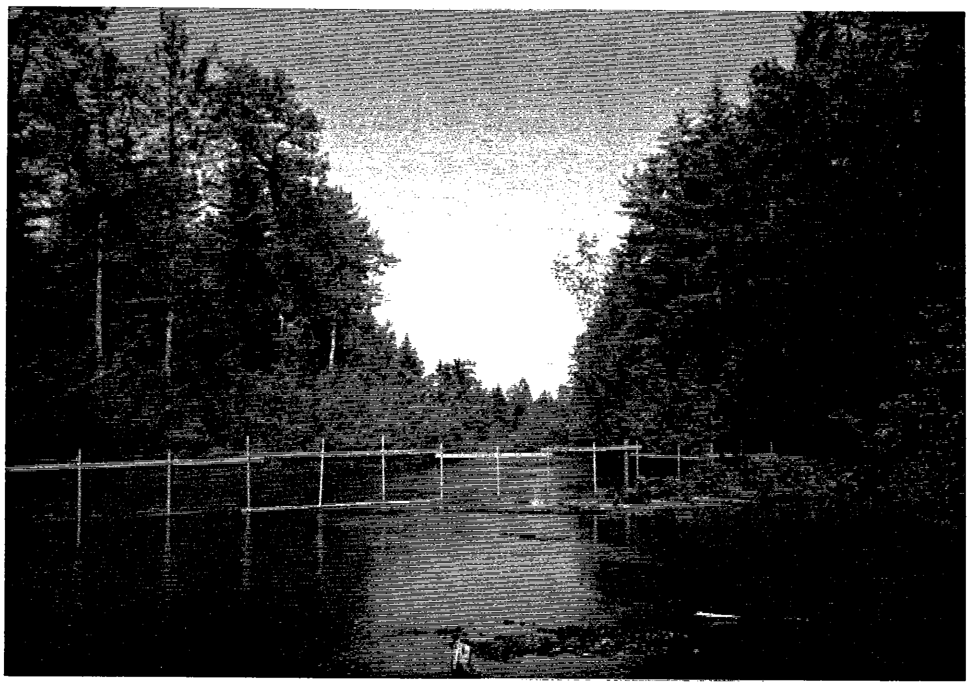

Figure 6.2—Weir on Old Situk River, May 1989.

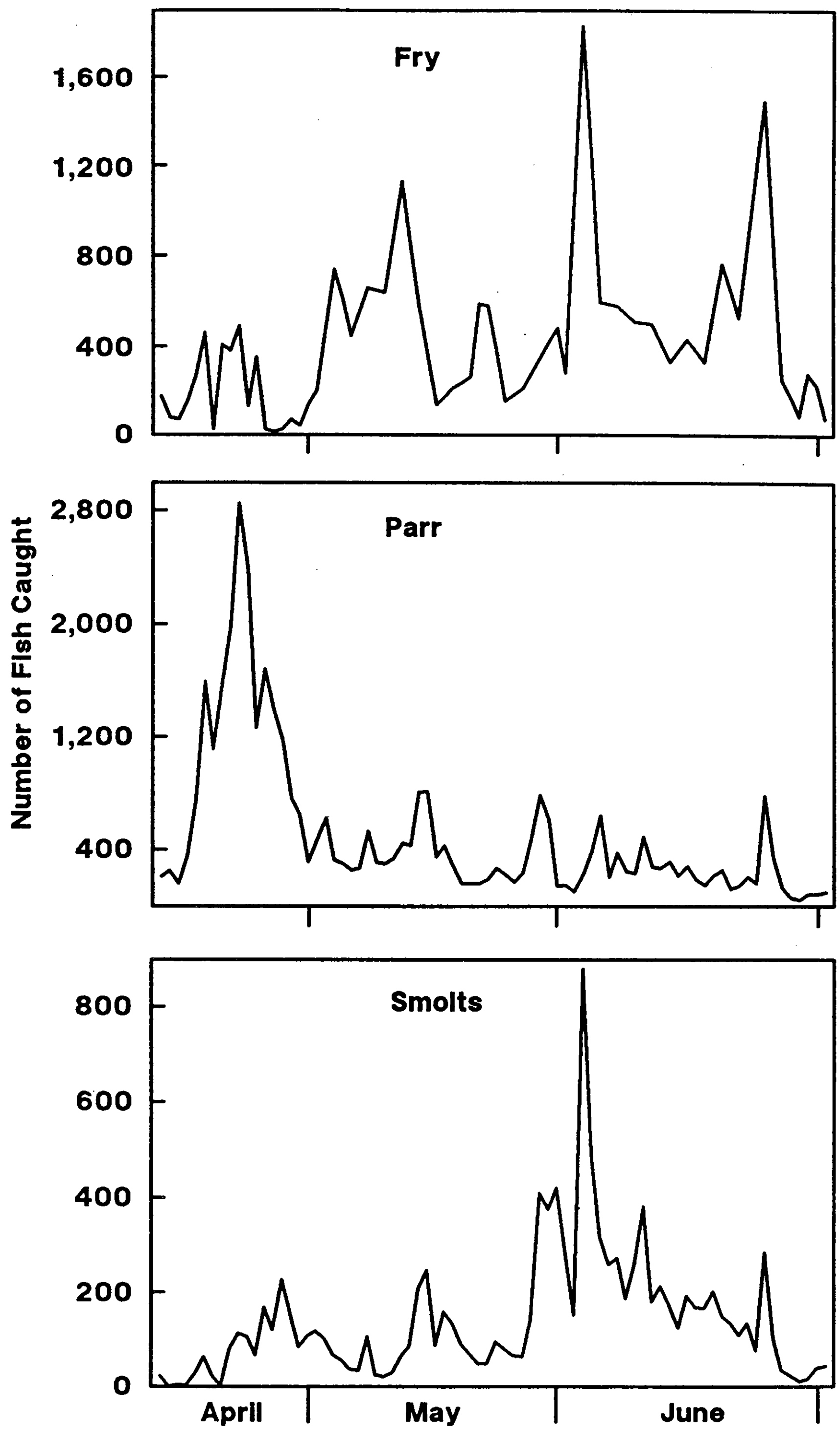

Figure 6.3—Daily catch of coho salmon at Old Situk River weir, 1989.

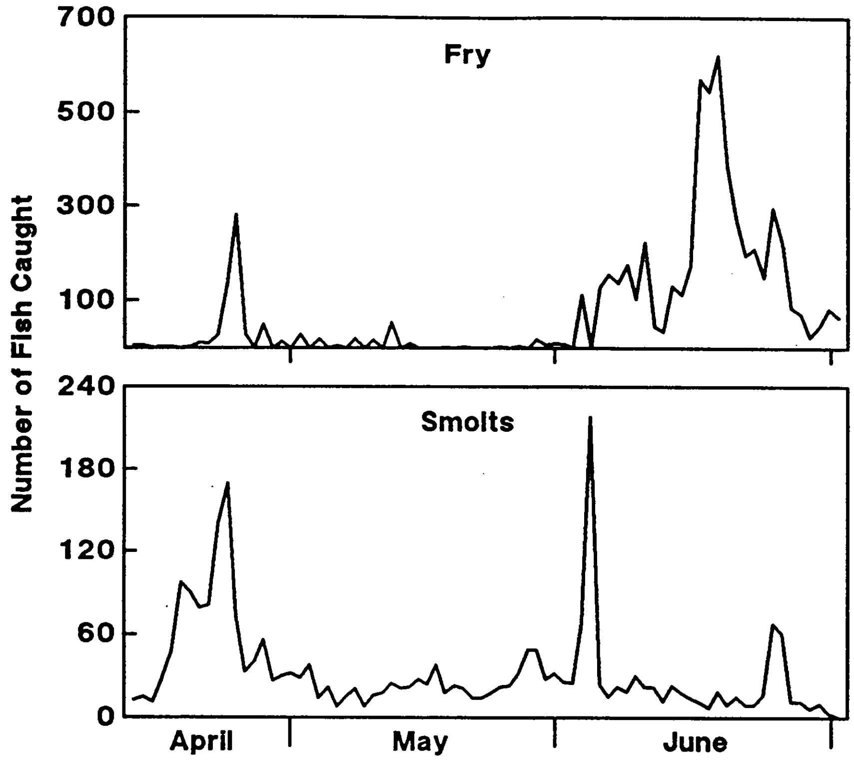

Figure 6.4—Daily catch of sockeye salmon at Old Situk River weir, 1989.

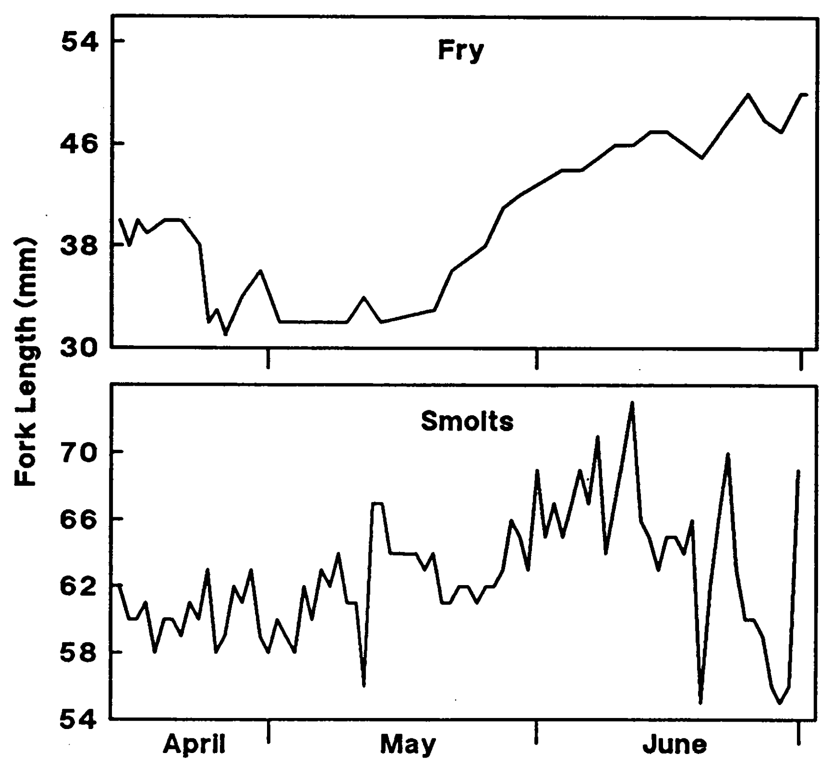

Figure 6.5—Daily mean fork length of sockeye salmon at Old Situk River weir, 1989.

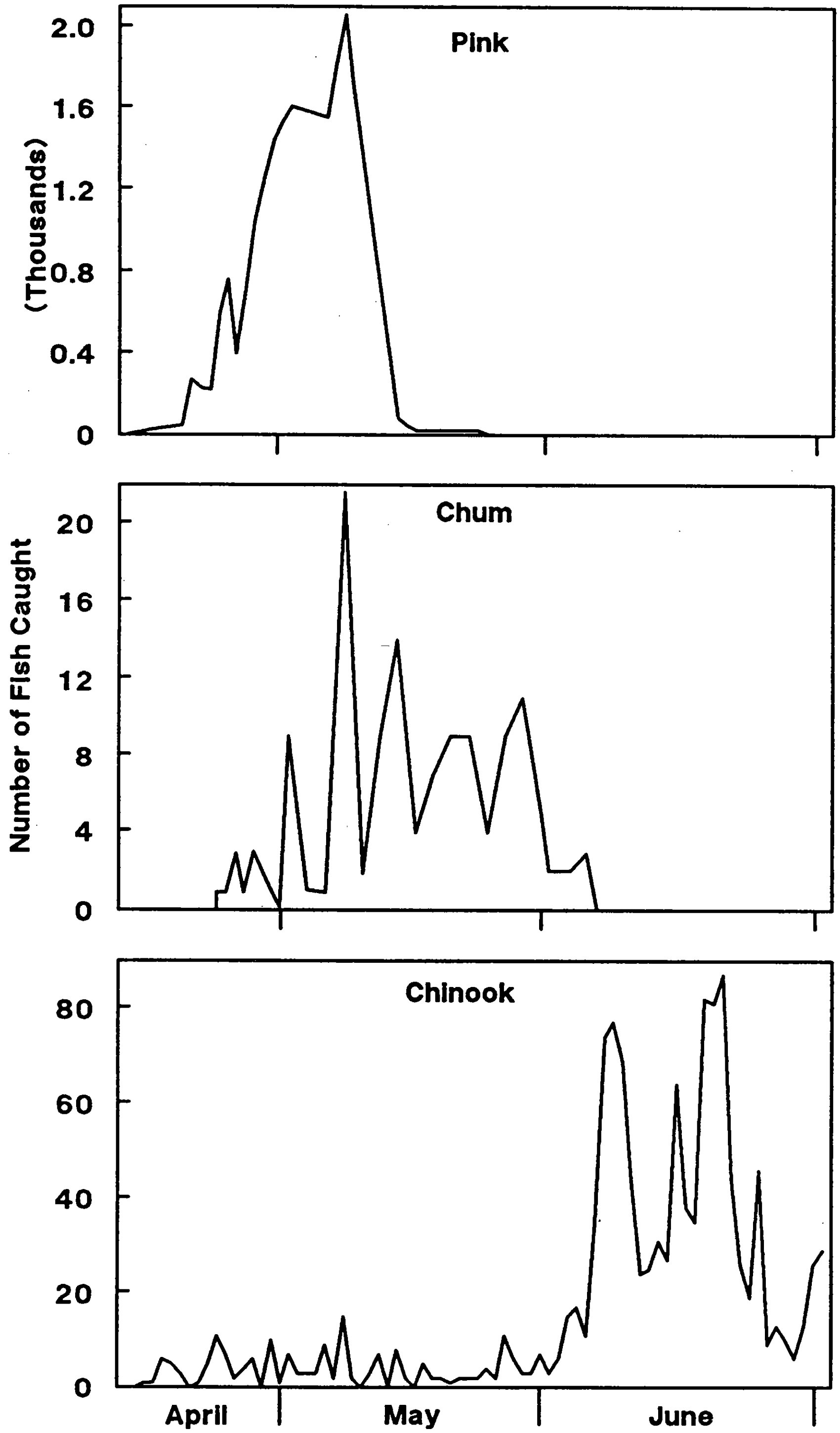

Figure 6.6—Daily catch of pink, chum, and chinook fry at Old Situk River weir, 1989.

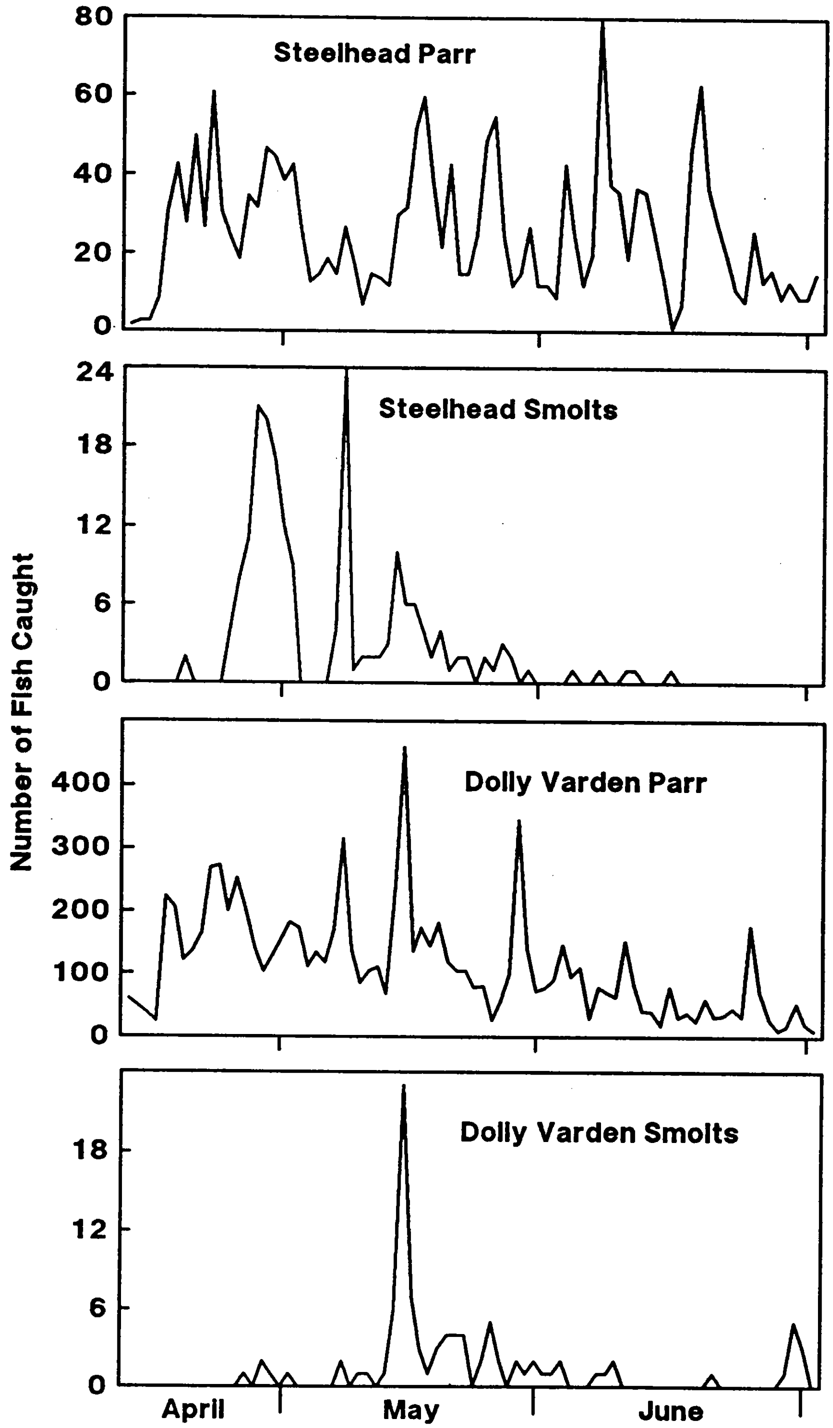

Figure 6.7—Daily catch of steelhead and Dolly Varden at Old Situk River weir, 1989.

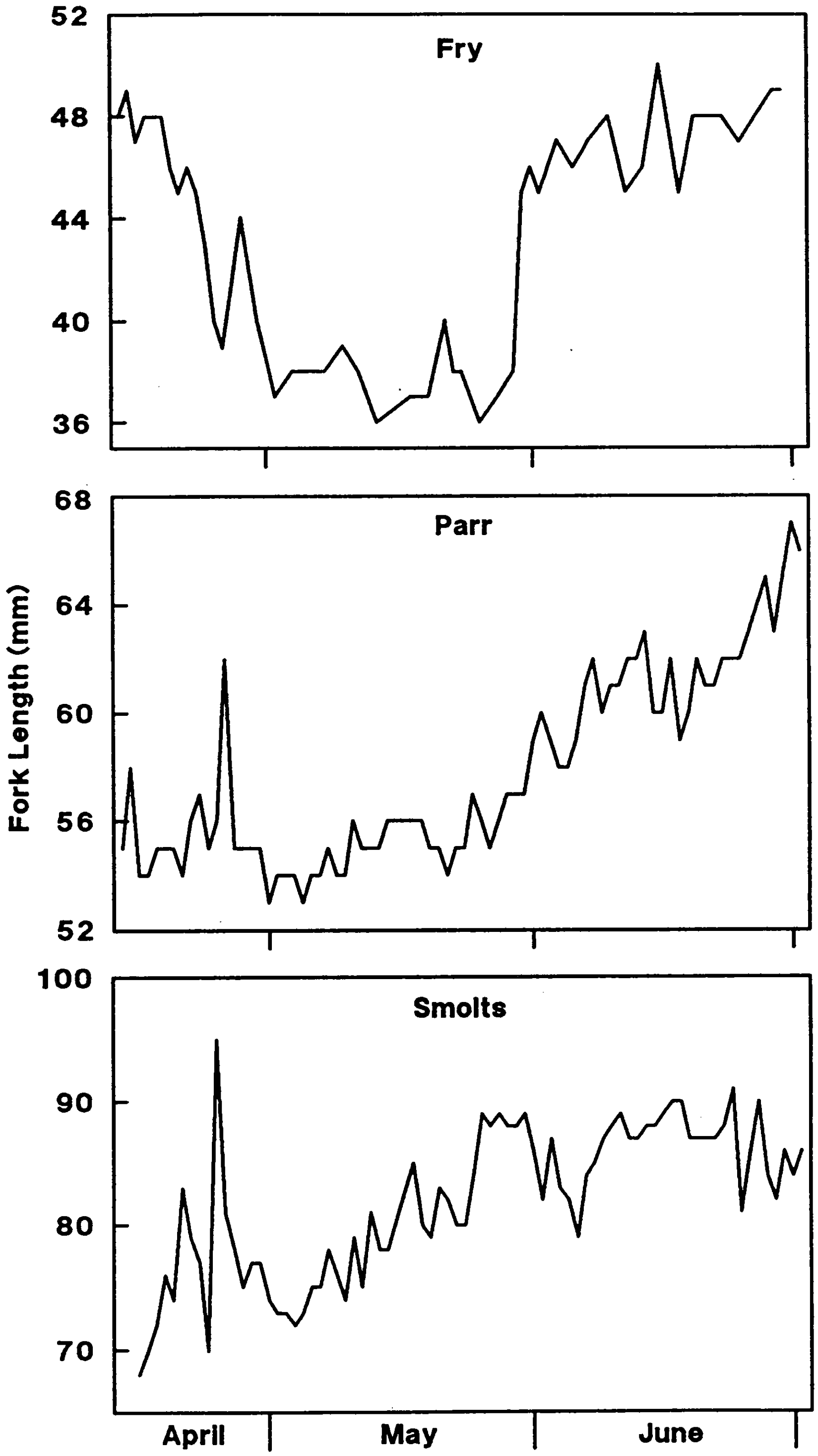

Figure 6.8—Daily mean fork length of coho salmon at Old Situk River weir, 1989.

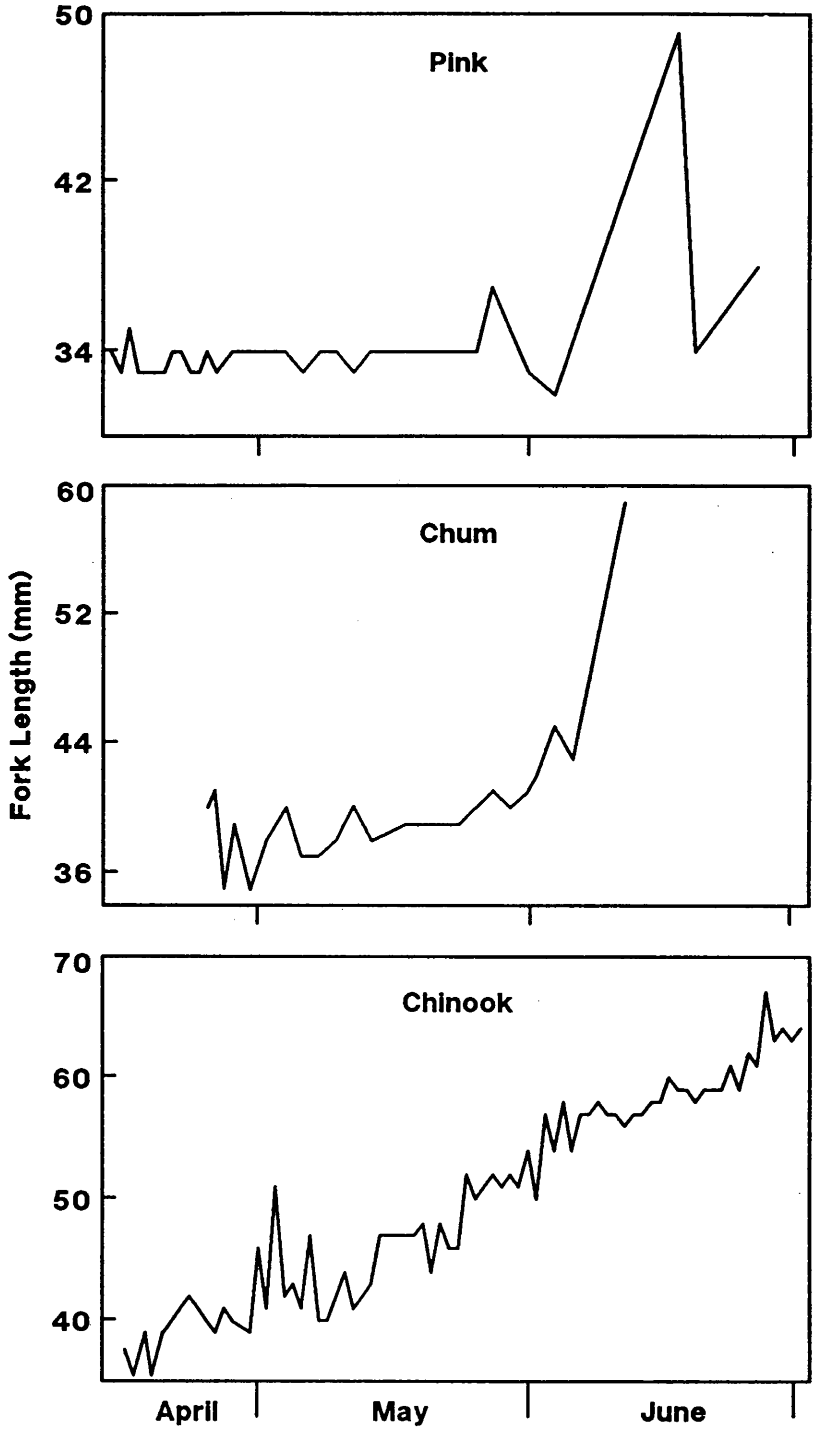

Figure 6.9—Daily mean fork length of pink, chum, and chinook fry at Old Situk River weir, 1989.

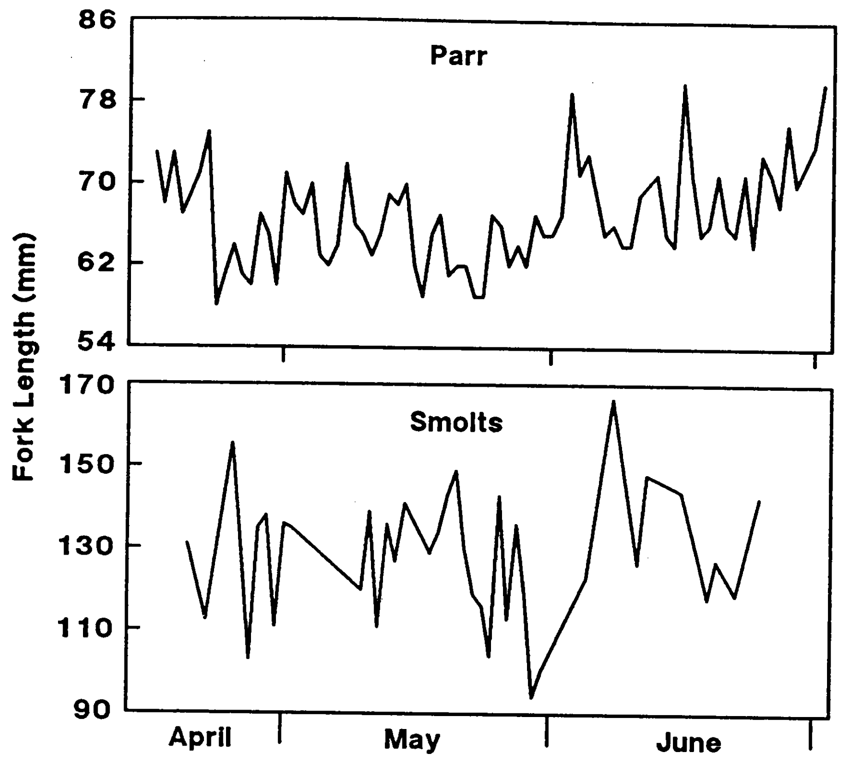

Figure 6.10—Daily mean fork length of steelhead at Old Situk River weir, 1989.

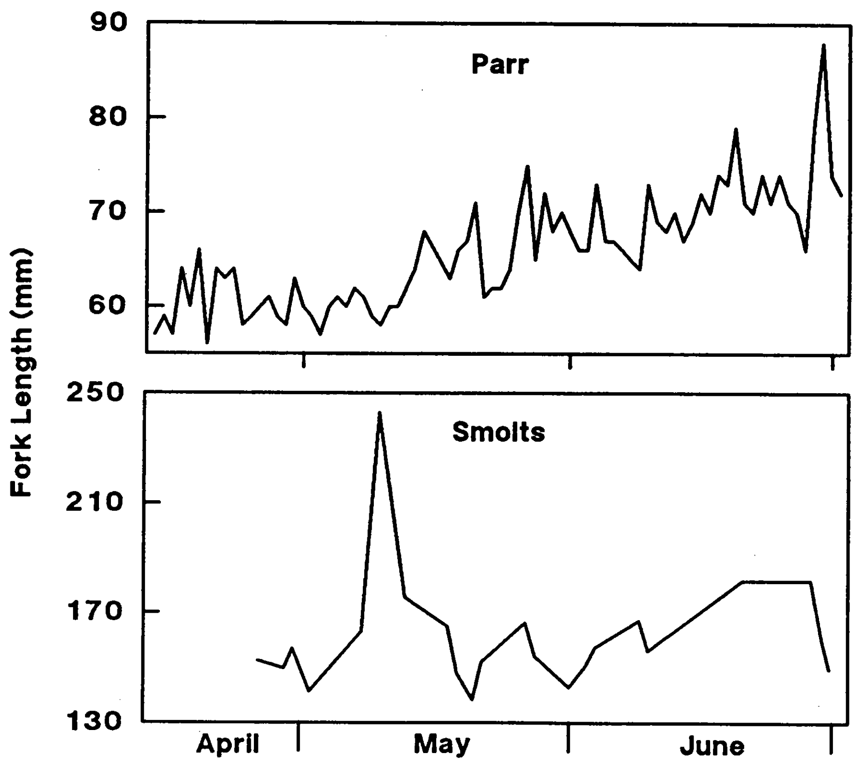

Figure 6.11—Daily mean fork length of Dolly Varden at Old Situk River weir, 1989.

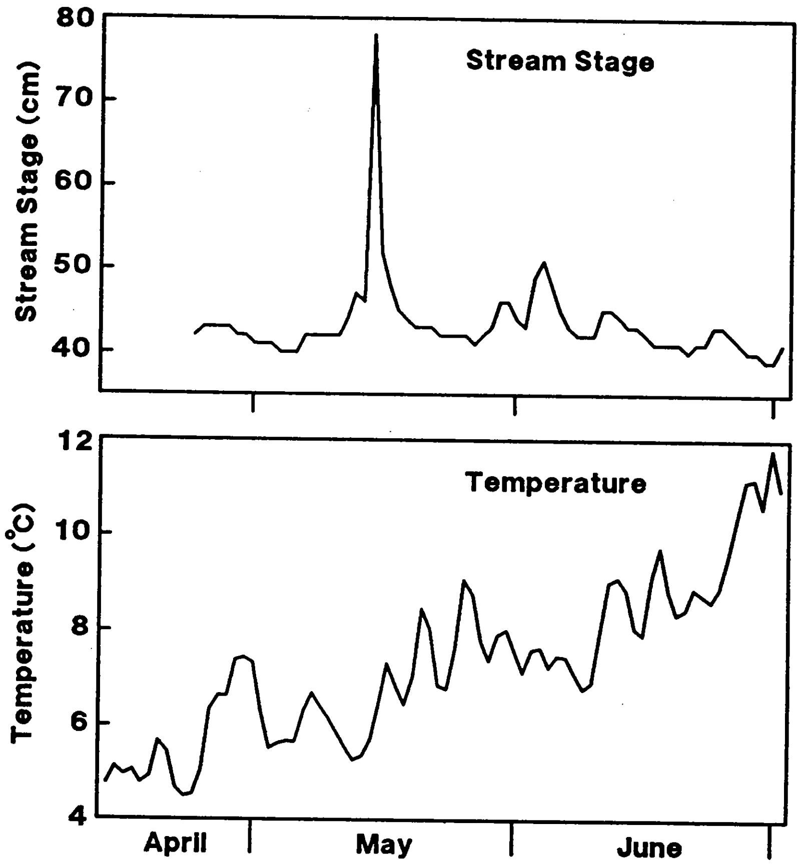

Figure 6.12—Daily stream stage and daily mean water temperature of Old Situk River, 1989.

STUDY 7.

SALMONID SMOLT YIELD FROM THE SITUK RIVER

Rationale

Salmonid smolt yield from the flood zone is a direct measure of potential impacts of flooding on salmonid production from the Situk River.

Objectives

Objectives of this study were to determine the total number of salmonid smolts that migrate in spring and summer from the entire Situk River; to partition smolt numbers from areas inside and outside the predicted flood zone; and to characterize migration timing, size, and age of migrant juvenile salmonids.

Summary of Results

Rotary-screw traps were fished at the upstream limit of the predicted flood zone and 3 km from the river mouth in 1990. Fish were marked and released 1 km upstream of each trap; recaptures were used to estimate fish numbers at each trap and survival between traps. Estimated total smolt yield from the river was 893,000 sockeye (including 128,000 ocean-type sockeye), 168,000 coho, 67,000 chinook, and 26,000 steelhead. Estimated survival between traps was 49% for coho smolts, 46% for chinook, and 84% for sockeye. High smolt mortality between traps probably was due to predation. Calculations based on the catch difference between the two traps indicate that 34% of sockeye (100% of ocean-type sockeye), 33% of coho smolts, 45% of chinook, and 0% of steelhead migrated from inside the flood zone.

METHODS

Fish Capture

Two rotary-screw traps were fished from April to mid-August 1990 at two sites: upriver, at the upstream limit of predicted flooding 20 km from the river mouth; and downriver, 3 km from the river mouth (Fig. 7.1). The upriver trap fished the area outside the flood zone; the downriver trap fished almost the entire river; the difference between traps represented the flood zone.

Each trap was a revolving stainless-steel, 2-mm-mesh cone on aluminum pontoons (Fig. 7.2). The cone entrance was 2.4 m in diameter, and one-half (2.2 m^2) was submerged. An internal screw rotated the cone 3-6 rpm depending on water velocity (which ranged 70-170 cm/s). Fish passing through the cone collected in a live box where a revolving drum removed small debris. The traps were tied to shore and braced in the thalweg at river constrictions (16 m wide upriver and 24 m wide downriver; 1.2-2.4 m deep at both sites). The trap fished 6-11% of river cross-section upriver and 4-8% downriver. We built fences (5 m long, 6-mm mesh) in a "V" shape in front of each trap to funnel fish into the traps. Mean daily water temperature ranged from

3°C in April to 16°C in August (Fig. 7.3). River stage (measured with a staff gauge at each trap) fluctuated because of storms at least once each month (Fig. 7.4).

Trapped fish were removed each day and sorted by size (fry, parr, and smolts) into flow-through boxes with negligible water velocity. Because few Dolly Varden parr and smolts were captured (121 upriver and 41 downriver), their yield could not be estimated; therefore Dolly Varden data are not included in this report. Up to 100 randomly selected fish per species and size group per week were measured for FL. Length frequencies for each species (combined size groups) were plotted by weighting each size group's frequencies (in 3- or 5-mm increments) by the group's proportion in the catch on days fry were enumerated. Fish ages determined from scale samples from up to 50 fish per species per week (except pink and chum) were compared with FL frequencies to determine age composition. Condition factor was calculated by dividing g weight by mm FL cubed (Ricker 1975) and multiplying by 10^5.

We enumerated parr and smolts daily and fry three times a week. To estimate fry on intervening days, we used the average catch in adjoining enumeration days. When too numerous to count, fry were estimated. Three samples of fry were weighed and counted by species; total numbers were calculated from mean weight and species composition of the samples and total weight of the fry catch. Size groups were adjusted as fish grew (Table 7.1). In April, for example, all fry were less than 45 mm long, and in July coho fry were less than 65 mm and steelhead fry were less than 50 mm. Chinook larger than 45 mm were always considered smolts. Sockeye fry were classified as ocean type regardless of size, if their eyes were small relative to their head size.

Smolt Yield

Numbers of migrant smolts and parr were estimated by the trap-efficiency method by releasing marked fish upstream of each trap. At least 3 days per week during the entire study, up to 1,000 smolts and 1,000 parr per species were marked with a tattoo as described in Study 4. We changed mark color on Monday and stopped marking on Thursday. Three colors (Alcian Blue, neutral red, and black India ink) were rotated the first 9 weeks. Neutral red was dropped after week 9 because of problems with retention and survival. Different mark positions were used at each trap. Upriver, salmon smolts were tattooed on the upper caudal fin or on both upper and lower caudal fin; steelhead smolts between the pelvic fins; and parr on the anal fin. Downriver, salmon smolts were tattooed on the lower caudal fin; steelhead smolts on the ventral caudal peduncle; and parr on both upper and lower caudal fin. Marked fish were held until dusk, moved in aerated tubs 1 km upstream, and released in quiet water. Recaptures were generally made soon after release: 2-28% within 1 d and 90% within 1 week. To estimate fish numbers, all recaptures were treated as if they occurred the same marking week as when released. Each day, all trapped smolts and parr were checked for marks, and up to 25 randomly selected recaptures of each species, size group, and mark were measured for FL.

Short-term mark survival (fish survival and mark retention) was determined by periodically holding a random sample of 25 marked fish per species. Fish were held in aerated tubs or flow-through boxes, and after 1 day, live fish with visible marks were counted. Short-term mark survival was calculated as

$$\hat{s} = s/h \; ; \tag{1}$$

$\hat{s}$ is estimated survival and retention of marks, s is number of surviving fish with visible marks, and h is number of marked fish held. The number of surviving marks was calculated as

$$\hat{M} = m\hat{s}\ ; \qquad (2)$$

$\hat{M}$ is estimated number of surviving marks, and m is number of marks released.

Mark retention and fish survival after 1 day were generally high, but differed between species ($P < 0.001$; G test) and mark color ($P < 0.001$). Mark retention was 100% for coho and chinook, but 96% for sockeye and 97% for steelhead. Blue and black marks were retained better (98-99%) than red marks (90%). Mark retention was a problem in weeks 8 and 9 because of Panjet malfunction; data from weeks 7 and 10 were averaged to estimate fish numbers in weeks 8 and 9. Sockeye smolts were fragile, and their 1-day survival (mean, 95%) was lower ($P < 0.05$) than for other smolts (mean, 99%; Table 7.2). Blue- or black-marked sockeye survived better ($P < 0.05$) than red-marked sockeye. Sockeye survival differed ($P < 0.01$) between marking weeks downriver, but was similar ($P = 0.32$) between weeks upriver.

The proportion of marked fish recaptured (trap efficiency) was used to expand the unmarked catch and estimate fish numbers. Trap efficiency was estimated by

$$\hat{E} = R/\hat{M}\ ; \qquad (3)$$

$\hat{E}$ is estimated trap efficiency, and R is number of marked fish recaptured. Fish number was estimated by

$$\hat{N} = U/\hat{E}\ ; \qquad (4)$$

$\hat{N}$ is estimated number of fish, and U is unmarked catch. Trap efficiency and mark survival were first calculated separately for each week and then tested for differences between consecutive weeks. If similar ($P > 0.05$; Chi-square test), data were pooled.

Trap efficiency differed widely between species and marking weeks (Fig. 7.5). Overall trap efficiency for smolts was greatest for chinook (24%), intermediate for coho (12%) and sockeye (7%), and least for steelhead (3%). Trap efficiency depended on river stage, position of the trap and fences, and amount of debris on the trap. Differences between species probably reflected differences in migratory behavior and ability to avoid the trap. Efficiency generally increased during the study as we adjusted traps and fences.

Size of recaptured smolts was compared with the size of marked fish released to determine whether trap efficiency differed by fish size within a species size group. Length frequencies of coho, chinook, and sockeye showed significant but small differences between marked and recaptured fish ($P < 0.05$; Kolmogorov Smirnov test). More recaptured fish than marked fish were middle-size range, but steelhead smolt recaptures were similar in size to the marked steelhead released ($P > 0.10$; Fig. 7.6). Thus, trap efficiency tended to be greater for the middle range size group, but differences were small, and the effect on population estimates was probably insignificant.

Variance for $\hat{N}$ each week was determined by the bootstrap method (Efron and Tibshirani 1986) with 1,000 iterations. Each bootstrap iteration involved calculating $\hat{N}^*$ by equations (1-4) after drawing s^* from the binomial distribution $(h,\hat{s})$, R^* from the binomial distribution $(\hat{M}, \hat{E})$, and U^* from the binomial distribution $(\hat{N}, \hat{E})$, where asterisks denote bootstrap values. Variance of weekly $\hat{N}$ was summed to obtain variance for the total migration[21].

[21]A Fortran program for calculating bootstrap variance is available from the authors on request.

Because ocean-type sockeye at the downstream trap were not distinguished from other sockeye until week 10, we partitioned sockeye estimates between ocean-type and other smolts in weeks 1-9 based on proportions of the age groups in the catch. The number in each age group was calculated as

$$\hat{N}_j = \hat{p}_j \hat{N} ; \tag{5}$$

$\hat{N}_j$ is estimated number of age group j; $\hat{p}$ is proportion of age group j; and $\hat{N}$ is estimated number of all sockeye. Variance (V) of each age group's $\hat{N}$ was calculated as

$$V(\hat{N}_j) = \hat{N}^2 V(\hat{p}_j) + \hat{p}_j^2 V(\hat{N}) + V(\hat{p}_j) V(\hat{N}) ; \tag{6}$$

symbols are defined above. Because few ocean-type sockeye were captured at the upstream trap, we did not distinguish between ocean-type and other sockeye.

Because fish mortality between traps would cause an underestimate of the flood zone's contribution, we estimated fish mortality from the equation

$$\hat{S} = R_d / (\hat{E}_d \hat{M}_u) ; \tag{7}$$

$\hat{S}$ is estimated survival of marked fish between traps; R_d is number of upriver-marked fish recaptured downriver; $\hat{E}_d$ is estimated efficiency of the downriver trap; and $\hat{M}_u$ is number of marks released at the upriver trap (after subtracting 1-day mortality). Important assumptions were that marking did not affect survival (other than initially), all surviving marked fish migrated past the downriver trap, and all recaptured marked fish were counted. Because many parr apparently remained in the area between traps and did not go to sea, their survival was not estimated.

RESULTS

Migration Characteristics

Sockeye smolts migrated mostly from mid-May to mid-July; ocean-type sockeye migrated primarily in June (Fig. 7.7). Overall, sockeye smolts were 64-89% age 1, and about 5% were age 2 (Table 7.3). Ocean-type sockeye were nearly one-third of the sockeye at the downriver trap but were rare upriver. Mean FL of age-1 and -2 sockeye was similar at both traps; the monthly mean ranged from 63 to 74 mm (Figs. 7.8, 7.9). Mean FL of ocean-type sockeye increased from 36 mm in April to 62 mm in July (Fig. 7.9).

Coho smolts migrated mostly from mid-May to late June, with peaks in late May upriver and early June downriver (Fig. 7.10); coho parr were most numerous in June and July (Fig. 7.10) during freshets (Fig. 7.4). Smolts were larger and older upriver than downriver ($P < 0.05$; Kolmogorov-Smirnov test). Mean FL was 107 mm upriver and 101 mm downriver (Figs. 7.11, 7.12). Nearly 60% were age 2 or 3 upriver, compared to 83% age 1 and 17% age 2 or 3 downriver (Table 7.3). The decline in size and age of smolts downriver could be explained by predation during migration between the traps and by an influx of smaller, younger smolts from inside the flood zone.

Chinook smolts migrated in June and July, beginning 1 week earlier upriver than downriver and peaking at both traps in July (Fig. 7.13). Some age-1 smolts (monthly means, 80-97 mm FL) were caught in April and May, but 99.9% of smolts were age 0 (Table 7.3; Figs. 7.14, 7.15). Mean FL of chinook smolts at the upriver trap increased gradually between June and August (from 66 to 85 mm upriver and from 61 to 89 mm downriver).

The migration of steelhead smolts was bimodal, particularly at the upriver trap (Fig. 7.16). Their number was greatest in late May and late June upriver, and in late June and mid-July downriver. The steelhead parr migration also was bimodal, with a small peak in mid-May and a larger peak in mid-June (Fig. 7.16). Age of smolts was similar at the two traps: 11% age 2, 82% age 3, and 7% age 4 (Table 7.3). Mean FL of smolts ranged from about 120 mm for age-2 smolts to 180 mm for age-4 smolts (Figs. 7.17, 7.18).

Condition of chinook and coho smolts was greater than sockeye and steelhead smolts (Table 7.4). Condition generally declined with age, except for sockeye at the upriver trap, where condition increased with age.

Rate of migration between the traps was greater for sockeye, coho, and steelhead smolts than chinook smolts. The time required to accumulate 90% of the downriver recaptures of upriver-marked smolts was 5 days for sockeye, 6 days for coho and steelhead, and 9 days for chinook (Fig. 7.19). Average migration rate of sockeye and coho (10 km/d) was two times faster than chinook (5 km/d). Some smolts from the upriver trap were recaptured downriver within 12 hours, indicating the fastest migration was 33 km/d.

Salmonid Fry

About 850,000 fry were caught upriver, and 4 million fry were caught downriver (Table 7.5). Pink fry far exceeded all other species, comprising 85% of fry upriver and 97% downriver. Coho fry were numerous, particularly upriver, and chum fry were numerous downriver. Few sockeye fry were caught and most were from downriver. Steelhead and chinook fry were uncommon upriver and were absent downriver. Based on the difference between traps, most pink, chum, and sockeye fry migrated from inside the flood zone, and most coho, steelhead, and chinook fry migrated from outside the flood zone.

Coho and steelhead fry migrated later than the other species (Figs. 7.20, 7.21). Coho fry migrated mostly from mid-April to late May upriver and from mid-June to August downriver. The coho fry migration peaked in mid-May upriver and in July downriver. Steelhead fry migrated from early July to early August at both traps. Pink, chum, sockeye, and chinook fry migrated mostly from mid-April to mid-May, with peaks in late April and early May.

Length of fry was generally greater downriver than upriver. Mean FL of ocean-type sockeye in June, for example, was 54 mm upriver and 58 mm downriver (Figs. 7.8, 7.9). Mean FL of coho fry increased from 35 mm in April at both traps to 51 mm upriver and 64 mm downriver in August (Figs. 7.11, 7.12). Mean FL of chinook fry upriver remained at 40 mm in April and May (Fig. 7.14), apparently because of continuous downstream migration of newly emerged fry. No chinook fry were caught downriver in April and May, and after May, they were considered smolts. Mean FL of steelhead fry in July and August was 33 mm upriver and 46 mm downriver (Figs. 7.17, 7.18). Mean FL of pink and chum fry from both traps was 35 and 37 mm, respectively.

Smolt Yield

About 117,000 smolts and 3,000 parr were trapped upriver; 69,000 smolts and 22,000 parr were trapped downriver (Table 7.6). Excluding fry, the upriver catch consisted of 62% sockeye smolts, 18% coho smolts, 16% chinook smolts, and 4% other groups; the downriver catch consisted of 35% sockeye smolts (including ocean type), 26% coho smolts, 23% coho parr, 14% chinook smolts, and 2% other groups. Thus, the main difference between traps was the greater proportion of coho parr at the downriver trap.

Based on estimated trap efficiency, a total of about 1.1 million parr and smolts passed the upriver trap, and 1.3 million passed the downriver trap (Table 7.6). Most of these migrants were smolts: 95% upriver and 90% downriver. Thus, the Situk River's total smolt yield was 1.2 million fish.

Sockeye made up most of the smolts at both traps (68% upriver and 77% downriver; Table 7.6). About 700,000 sockeye smolts (probably of lake origin) passed the upriver trap, and 765,000 smolts and 128,000 ocean-type sockeye passed the downriver trap. Total smolt yield from the Situk River was nearly 900,000 sockeye.

Estimated coho smolts were more numerous at the upriver trap than downriver ($P < 0.01$; *t*-test): 230,000 upriver but only 168,000 downriver—a 27% decline (Table 7.6). Parr, however, were much more numerous downriver than upriver: 127,000 downriver compared to 31,000 upriver. By catch difference, nearly 100,000 parr came from the flood zone, and an unknown number of these became smolts. The combined total of coho parr and smolts was 261,000 upriver and 295,000 downriver.

As with coho smolts, estimated chinook smolts were more numerous upriver than downriver ($P < 0.01$; *t*-test): 80,000 passed upriver, but only 67,000 passed downriver—a 16% decline (Table 7.6). This apparent decline would be greater if chinook fry that moved downstream in spring were added to the upriver population estimate. Chinook fry were not estimated by mark-recapture because of small size (<45 mm FL), but 2,149 chinook fry were caught in the upriver trap in April and May, and no fry were caught downriver. Based on likely trap efficiency of 5%, over 40,000 chinook fry probably entered the flood zone in spring and later migrated past the downriver trap. Thus, the total loss of chinook smolts and fry between traps was probably about 44%.

Estimated steelhead smolts were equally abundant (26,000 fish) at both traps (Table 7.6). Parr, however, were more numerous upriver than downriver: 28,000 upriver and only 8,000 downriver. The difference between traps indicates that about 20,000 parr migrated into the flood zone and remained there. Precision of estimates, however, was poor for both smolts and parr because of low trap efficiency (0-15%).

Estimated survival of marked fish between the upriver and downriver traps corroborated the decline in smolt populations between traps. Survival of marked smolts was 49% for coho, 46% for chinook, and 42% for sockeye (Table 7.7); too few steelhead were caught to estimate survival. Survival of coho and chinook stayed in a narrow range of only 38-42% during most of the migration. Chinook survival increased to 81-90% in the last 2 weeks. Sockeye survival was variable, ranging from 4 to 69%.

Survival of sockeye could have been underestimated because of delayed handling mortality. Initial handling mortality was negligible (<1%) in coho, chinook, and steelhead, but was nearly 3% in sockeye smolts (Table 7.8). Handling mortality in recaptured coho, chinook, and steelhead was also negligible, but about 6% in sockeye, indicating a delayed mortality from marking in sockeye.

Problems identifying marks also contributed to underestimating survival of sockeye. Mark recognition was tested in June by double marking sockeye on both upper caudal (the usual upriver mark) and lower caudal (the downriver mark) and releasing them at the upriver trap along with regular releases. At the downriver trap, double marks were observed at nearly three times the rate of single marks ($P < 0.001$; Chi-square test; Table 7.9), indicating that workers were less efficient in observing marks from upriver than marks applied by themselves. Because of this bias, sockeye survival may have been underestimated by two-thirds. An estimate of sockeye survival based only on double-caudal marks was 79% (Table 7.10).

Based on the difference in smolt populations at the two traps and estimated survival of smolts between the traps, the contribution from the flood zone to the river's total smolt yield was 33% of coho, 45% of chinook, and 34% of sockeye (Table 7.11). Because of possible incomplete mark recognition, delayed handling mortality of marked fish, and increased vulnerability of marked fish to predators, smolt survival between traps may have been underestimated and the contribution from the flood zone may have been overestimated.

DISCUSSION

Migration Characteristics

Migration timing of coho, sockeye, and steelhead smolts in the Situk River was similar to other Alaska rivers. The peak migration of coho smolts in early June is similar to that reported by Thedinga and Koski (1984) and Crone and Bond (1976), and the peak migration of sockeye smolts in early June is similar to that reported by Foerster (1968). Peak migration of steelhead smolts in the Situk River (mid-June) was 1 week later than in Petersburg Creek (Jones 1974).

Age of sockeye smolts was similar to other rivers in the Yakutat forelands (McBride 1986), but it differs from most of Alaska because of the ocean-type stock. Migration timing and size of ocean-type sockeye were similar to that in the Taku River, Southeast Alaska (McPherson et al. 1988; Murphy et al. 1991); ocean-type sockeye from both rivers migrate in mid-June at a mean FL of 54-58 mm.

Age and migration timing were unusual for Alaska chinook and resembled ocean-type chinook in the Pacific Northwest and British Columbia (Healey 1983). Except for the Deshka River (Delaney et al. 1982), Alaska chinook smolts are mostly age 1 (Taylor 1990). Peak migration in other Alaska rivers is in late May (e.g., Murphy et al. 1991); in the Situk River, the peak was in July. Smolt trapping verifies conclusions from Study 4 that most Situk River chinook go to sea at age 0.

The migration rate of smolts was comparable to other studies. Sockeye smolts migrated 10 km/d in the Situk River, 5-8 km/d in the Babine Lake, British Columbia, watershed (Johnson and Groot 1963), and at least 6 km/d in Little Togiak Lake and 7 km/d in Lake Nerka, Alaska (Burgner 1962). Coho smolts in the Chehalis River, Washington, migrated 29 km/d (Moser et al. 1991) compared to a maximum of 33 km/d in the Situk River. Chinook smolts in the Sacramento River migrated 10-18 km/d (Kjelson et al. 1982), more than twice the 5 km/d in the Situk River.

Smolt Yield

The lower numbers of coho and chinook smolts at the downriver trap than at the upriver trap can best be explained by mortality of fish as they migrated between the traps. Surveys of the main-stem river in August and September showed negligible numbers of smolts that may have remained in fresh water rather than migrating to sea (Study 3). Differences in trap efficiency also do not explain the loss of smolts because mark-recapture methods accounted for differences in catchability. Thus, the decline in fish between traps probably resulted from mortality in the main-stem river.

Predation could account for high smolt mortality. River otters (*Lutra canadensis*), mink (*Mustela vison*), common mergansers (*Mergus merganser*), belted kingfishers (*Megaceryle alcyon*), and great blue herons (*Ardea herodias*), as well as Dolly Varden, are all common in the Situk River and are potential predators of juvenile salmonids (Alexander 1979; Wood 1987). Abundant salmonid fry and smolts may attract predators to the river, and such predator concentrations could cause high smolt mortality. Predation mortality of Atlantic salmon smolts in two Swedish rivers was 50% (Larsson 1985), and mergansers caused up to 10% mortality in juvenile salmonids in a British Columbia stream (Wood 1987). At least 100 mergansers occur along the Situk River during the smolt migration (senior author's pers. observ.). If each merganser consumed 400 g of fish per day (Wood and Hand 1985) during the 7-week smolt migration, they would consume 200,000 10-g smolts. The combined effect of all predator species could explain the observed loss of migrating smolts.

Sockeye and steelhead smolts did not decline between traps, indicating less predation than coho and chinook. The principal source of sockeye smolts inside the flood zone is probably Old Situk River, but it produces only about 6,000 age-1 smolts (Study 6), and there are no known sources of large numbers of steelhead smolts. Thus, sockeye and steelhead smolts appear to have much lower mortality during migration than coho and chinook, perhaps because of differences in size and behavior. Sockeye migrated faster than either coho or chinook, and steelhead were the largest and most secretive. More research is needed to assess predator-prey relationships in migrating smolts.

Predation mortality in migrating smolts appears to be greater than generally realized. Losses are more evident when smolt yield is partitioned between different areas of a watershed. In our study, we did not anticipate that more than one-quarter of the migrating smolts would disappear between upriver and downriver traps. Such heavy mortality may have important consequences for a river's salmon production and a manager's ability to conserve or restore depleted salmon stocks. More research is needed to fully quantify predation of migrating smolts and assess its consequences for fisheries.

Our estimates of the number of chinook, sockeye, and steelhead smolts appear realistic compared to expected smolt yields based on average production of adults. For chinook, if the estimated 67,000 smolts had a marine survival of 3% (Lister and Argue 1989), they would produce 2,010 adults; the river's average adult return is 2,000. For sockeye, if the 900,000 smolts had a marine survival of 10% (Foerster 1968), they would produce 90,000 adults; the average return is 100,000 adults. For steelhead, if the estimated 26,000 smolts had a marine survival rate of 16% (Ward and Slaney 1988), they would produce 4,160 adults; the average return is 5,000 adults (Johnson 1990, 1991).

Our estimate of coho smolts appears low compared to expected smolts based on average coho returns. The estimated 168,000 coho smolts would have to survive at a 36% rate to produce the average return of 60,000 adults. Marine survival of coho typically ranges from 5 to 20% (Shapovalov and Taft 1954; Thedinga and Koski 1984; Elliott and Sterritt 1991). The true number of smolts was probably underestimated because many age-1 parr (which we estimated separately from smolts) later transformed to smolts and migrated to sea. The combined number of parr and smolts was about 300,000 fish, which would produce 60,000 adults if marine survival was 20%. The coho parr migration from Old Situk River peaks in April (Study 6), providing plenty of time for the nearly 100,000 parr from there to grow enough to become smolts.

Loss of marks and mortality of marked fish would decrease trap efficiency, causing an overestimate of smolts. Overall mark retention and short-term survival were high at both traps. Other studies have demonstrated high survival and good mark retention of tattooed fish. Alcian blue tattoos on the ventral body are recognizable for at least a year (Cane 1981), and coho parr we marked in the laboratory with blue and black tattoos showed 100% survival and mark retention after 2 months. Mark loss, therefore, probably did not affect population estimates. Mortality could be important if marking increases a fish's vulnerability to predators. Because most marked fish quickly migrated back downstream past the trap (90% within 1 week), effects of mark mortality on our results were probably minor.

Few other studies have used two traps to partition smolt yield between areas of a river. Dempson and Stansbury (1991) used two traps 10 km apart to estimate number of Atlantic salmon smolts migrating from the Conne River. Our study demonstrated that smolt yield can be partitioned, but methods must account for fish mortality between traps and mark recognition efficiency.

Although smolt yield is probably the best measure of salmonid production from a watershed as a whole, it may give only a partial measure of the contribution of specific areas within a watershed. Fish move seasonally, complicating the assessment of an area's production. In the Situk River, an estimated 70% of the river's juvenile salmonids rear in the flood zone in summer, but many move to other wintering areas from which they migrate to sea the following spring. Many parr also migrate to staging areas in spring before they develop smolt characteristics. Complementary studies of summer rearing areas (Study 3) and surveys for residual parr (Study 4) should be considered along with smolt yield to fully evaluate the contribution from the flood zone.

Table 7.1—Size range of different size groups of each species by marking week for fish caught at upriver and downriver traps, Situk River, 1990.

Species	Week	Size range (mm)
Coho:		
fry	1-7	<45
	8-10	<50
	11-12	<55
	13-20	<60
parr	1-7	45-60
	8-10	50-70
	11-12	55-70
	13-20	60-75
smolt	1-7	>60
	8-10	>70
	11-12	>70
	13-20	>75
Sockeye:		
fry	1-12	<45
	13-20	<50
smolt	1-12	≥45
	13-20	≥50
Chinook:		
fry	1-20	<45
smolt	1-20	≥45
Steelhead:		
fry	1-20	<45
parr	1-11	45-100
	12-20	45-120
smolt	1-11	>100
	12-20	>120

Table 7.2—Percent survival of smolts held 24 h after marking at upriver and downriver traps, May to July 1990. A dash indicates no test.

Mark		Survival (%)			
Week	Color	Coho	Sockeye	Chinook	Steelhead
		Upriver			
5/07 - 5/13	Black	100	100	—	100
5/21 - 5/27	Red	100	89	—	—
5/28 - 6/03	Blue & Red	100	98	—	100
6/04 - 6/10	Black	100	92	—	—
6/11 - 6/17	Black	100	100	100	100
6/18 - 6/24	Blue	—	100	—	—
6/25 - 7/01	Black	90	97	100	—
7/02 - 7/08	Blue	100	78	—	100
7/16 - 7/22	Blue	—	98	—	—
		Downriver			
5/07 - 5/13	Red	100	97	100	100
5/21 - 5/27	Black & Red	100	99	—	100
5/28 - 6/03	Black & Red	100	90	—	100
6/04 - 6/10	Blue	100	100	—	—
6/11 - 6/17	Black & Blue	100	100	—	100
6/18 - 6/24	Red	—	89	—	—
6/25 - 7/01	Blue	100	97	94	100
7/09 - 7/15	Blue	100	—	100	—

Table 7.3—Age composition of juvenile salmonids captured in upriver and downriver traps in the Situk River, April to August 1990.

Species	Total aged per species	Age composition (%) 0	1	2	3	4
		Upriver				
Coho smolt	245		44.2	47.8	8.0	
Coho non-smolt		94.6	5.2	0.2		
Sockeye smolt	170	4.5	89.4	6.1		
Chinook smolt	55	99.9	0.1			
Steelhead smolt	112		0.3	6.6	83.0	10.1
Steelhead non-smolt		37.1	51.3	5.5	5.6	0.4
		Downriver				
Coho smolt	309		82.7	16.8	0.5	
Coho non-smolt		73.8	26.0	0.2		
Sockeye smolt	241	32.8	63.7	3.5		
Chinook smolt	99	99.9	0.1			
Steelhead smolt	112			7.3	80.1	12.6
Steelhead non-smolt		6.8	70.7	12.4	10.1	

Table 7.4—Condition factor of smolts captured in the upriver and downriver traps in the Situk River, April to August 1990. Standard deviation is in parentheses.

Age	Coho	Sockeye	Chinook	Steelhead
		Upriver		
0		0.81 (0.08)	0.99 (0.17)	
1	0.98 (0.11)	0.85 (0.14)		
2	0.98 (0.04)	0.87 (0.10)		0.95 (0.35)
3	0.95 (0.04)			0.90 (0.19)
4				0.87 (0.08)
		Downriver		
0		0.89 (0.08)	1.03 (0.08)	
1	0.99 (0.07)	0.85 (0.15)		
2	0.96 (0.06)	0.82 (0.07)		0.92 (0.05)
3				0.84 (0.07)
4				0.88 (0.06)

Table 7.5—Estimated catch of salmonid fry in upriver and downriver traps on the Situk River, April to August 1990. On days they were not counted, number of fry was estimated by extrapolating the catch from adjacent days.

	Catch (thousands of fish)	
Species	Upriver	Downriver
Pink	729	3,907
Chum	1	83
Coho	120	33
Sockeye	1	6
Chinook	2	0
Steelhead	2	0
Total	855	4,029

Table 7.6—Total catch and estimated number ($\hat{N}$) of juvenile salmonids at upriver and downriver traps on the Situk River, April to August 1990.

	Catch		$\hat{N}$ in thousands of fish (95% C.I.)	
Species, stage	Upriver	Downriver	Upriver	Downriver
Sockeye smolts:				
Age >0	74,460	30,125	701 (646-756)	765 (545-984)
Age 0	0	1,179	0 (0-0)	128 (90-166)
Coho:				
Smolts	22,131	23,740	230 (216-244)	168 (138-197)
Parr	1,997	20,941	31 (22-40)	127 (116-142)
Chinook smolts	19,335	13,033	80 (74-85)	67 (59-68)
Steelhead:				
Smolts	1,124	534	26 (15-38)	26 (0-72)
Parr	1,466	659	20 (15-41)	8 (5-12)
Total	120,513	90,211	1,088	1,289

Table 7.7—Smolt survival between traps, calculated from upriver marks released, downriver recaptures, and downriver trap efficiency. Symbols refer to equation (5). Data included are for weeks with >100 marked fish released. Data for weeks 8 and 9 were omitted because of Panjet malfunction. Too few steelhead were caught to estimate survival.

Week	Marks released ($\hat{M}_u$)[a]	Recaptures downriver (R_d)[b]	Expanded marks ($R_d/\hat{E}$)[c]	% Survival of marks ($\hat{S}$)
		Coho smolts		
10	1,836	146	1,209	66
11	1,528	107	630	41
12	1,409	99	558	40
13	638	33	251	39
15	114	8	48	42
Total	5,539	325	2,696	49
		Chinook smolts		
11	159	7	35	22
12	1,177	103	483	41
13	834	66	354	40
14	879	100	338	38
15	762	63	320	42
16	769	48	307	40
17	444	59	400	90
18	194	20	157	81
Total	5,218	466	2,394	46
		Sockeye smolts		
6	417	1	18	4
7	1,213	9	287	24
10	934	10	511	55
11	1,214	15	837	69
12	1,647	23	713	43
13	1,150	21	409	36
14	711	50	271	38
15	639	26	347	54
16	170	1	39	23
Total	8,095	156	3,432	42

[a]Estimated number after accounting for 24-h survival and mark retention.

[b]Total recaptures over 1-3 week period.

[c]Number of recaptures divided by downriver trap efficiency in week of recapture.

Table 7.8—Handling mortality of smolts and parr caught in the upriver trap.

	Released alive	Died	% Mortality
		Unmarked catch	
Coho	75,357	64	0.1
Chinook	20,104	44	0.2
Steelhead	3,239	23	0.7
Sockeye	73,018	2,016	2.7
		Recaptured fish	
Coho	806	6	0.7
Chinook	1,398	6	0.4
Steelhead	55	0	0.0
Sockeye	1,021	64	5.9

Table 7.9—Comparison of the percentage of sockeye marked with single and double-caudal tattoos, released at the upriver trap, and later observed at the downriver trap. Data are from marking weeks 12 and 13 only.

	Single black	Single blue	Double black or blue
Marks released upriver	1,313	982	503
Number observed downriver	14	13	16
% Observed downriver	1.1	1.3	3.2

Table 7.10—Estimated survival of double-caudal marked sockeye between traps in the Situk River, 18 June to 1 July 1990, based on equation (5). Symbols are defined in the text.

Week	Marks released ($\hat{M}_u$)	Downriver recaptures (R_d)	Trap efficiency ($\hat{E}_d$)	Expanded recaptures ($R_d/\hat{E}_d$)	% Survival ($\hat{S}$)
12	334	8	0.032	250	
13	164	7	0.050	140	
14	0	1	0.184	5	
Total	498	16		395	79

Table 7.11—Estimated contribution of the flood zone, based on difference in estimated number of smolts at upriver and downriver traps and estimated survival between traps. Smolt numbers ($\hat{N}$) are in thousands.

	Upriver $\hat{N}$	% Survival	Upriver survivors	Downriver $\hat{N}$	% Flood zone contribution
Coho	230	49	113	168	33
Chinook	80	46	37	67	45
Sockeye	701	84*	589	893	34

*Survival based on double-caudal marks only (79%) and estimated 6% marking mortality (Tables 7.8 and 7.10).

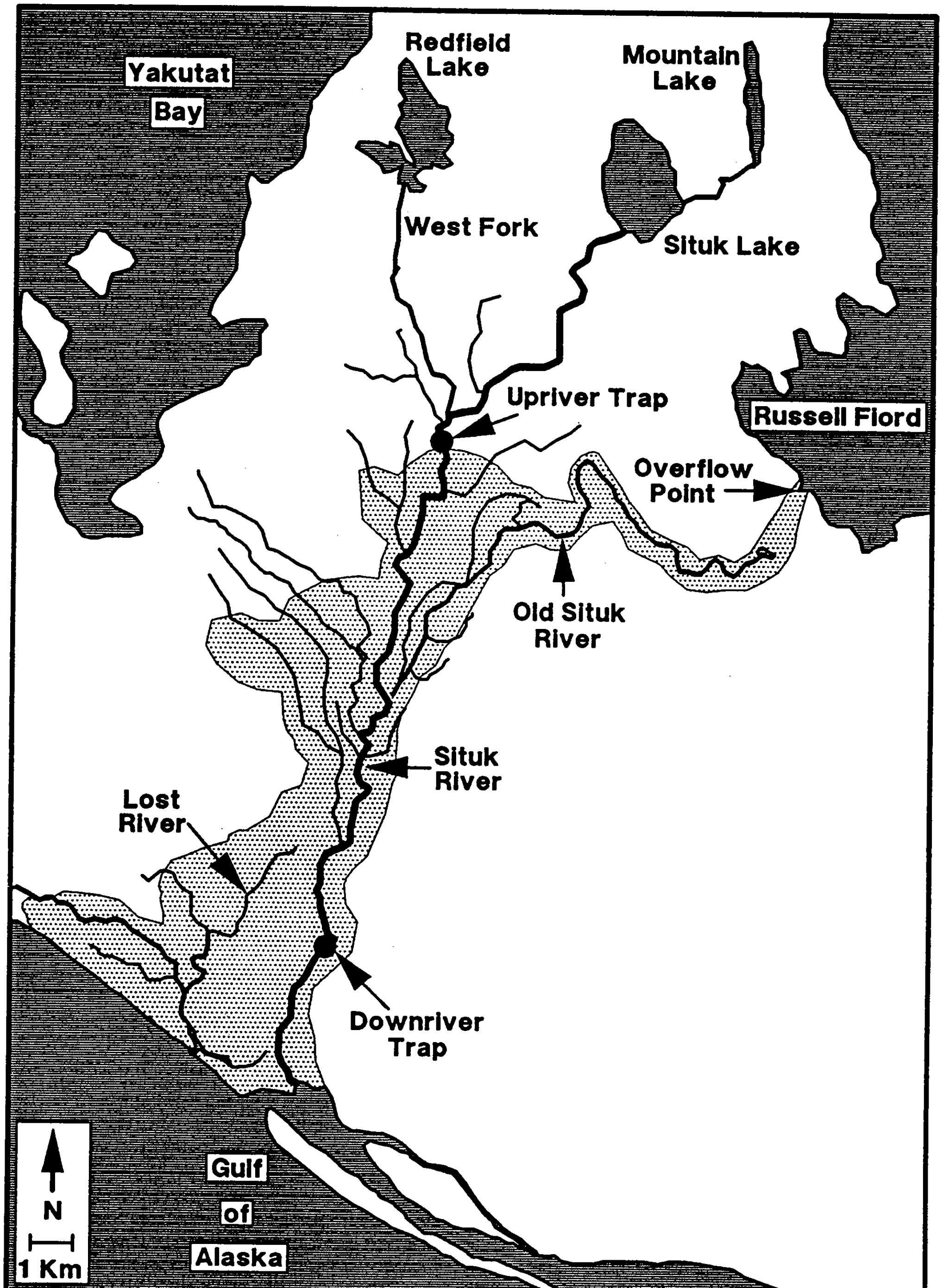

Figure 7.1—Map showing location of two rotary-screw traps used to catch juvenile salmonids on the Situk River. The predicted flood zone is stippled.

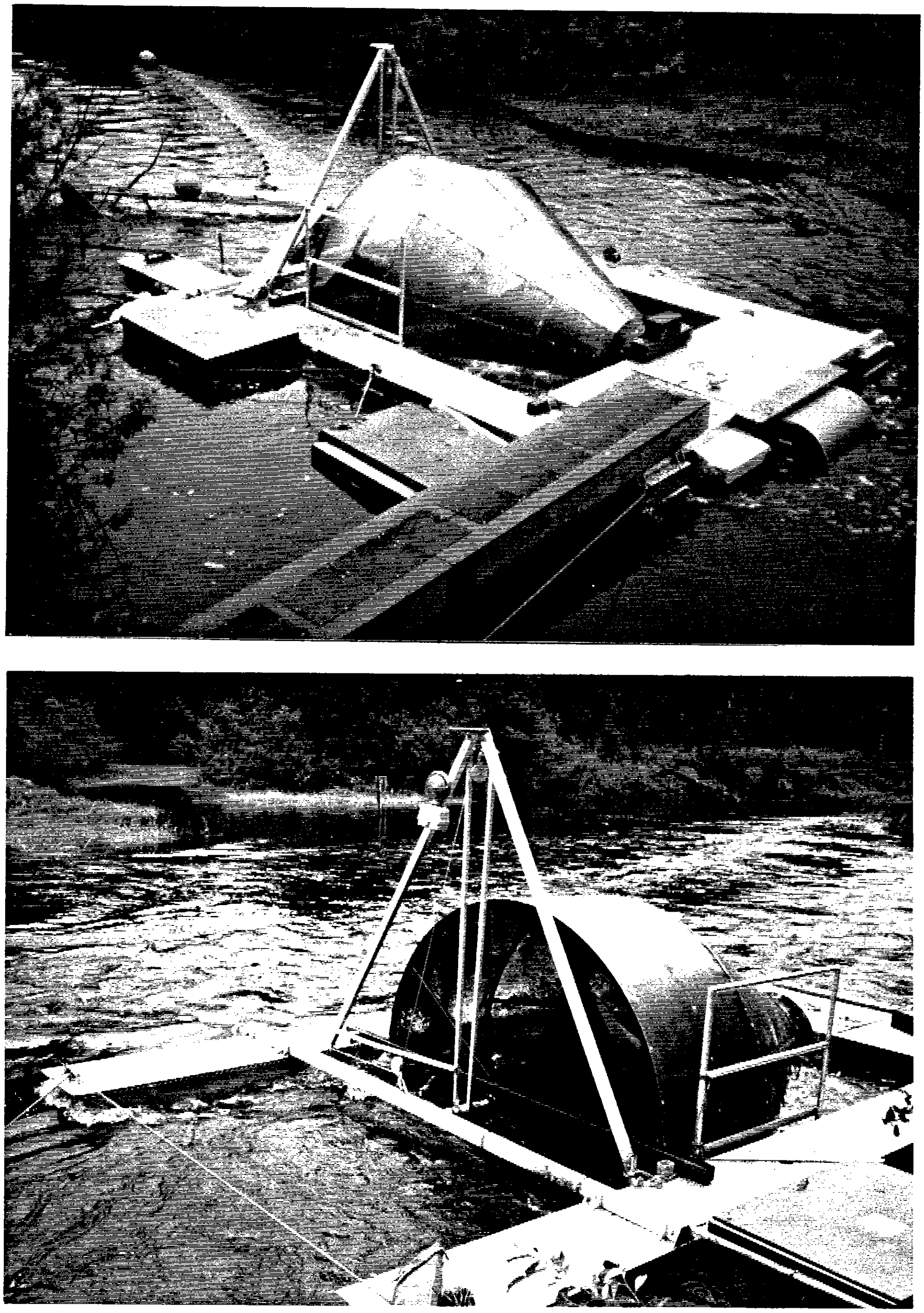

Figure 7.2—Rotary-screw fish trap on the Situk River in April 1990.

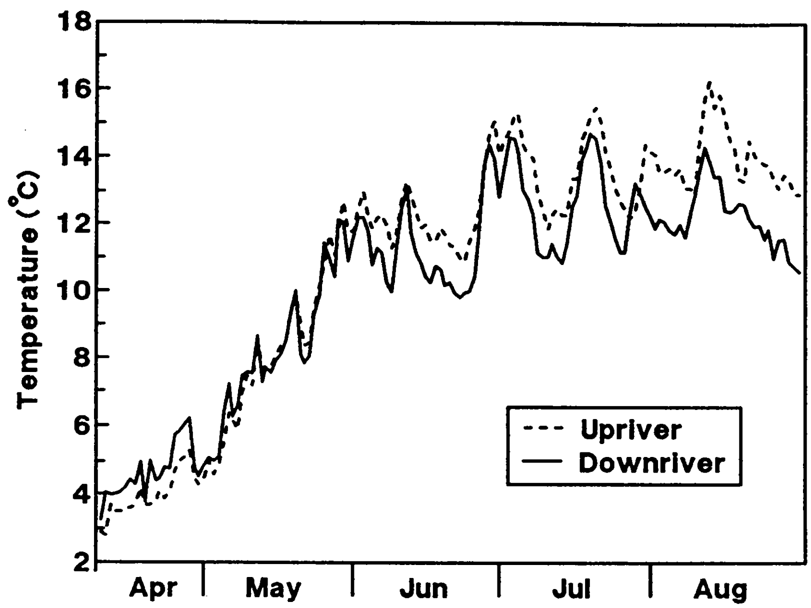

Figure 7.3—Mean daily water temperature of the Situk River at upriver and downriver traps, April to August 1990.

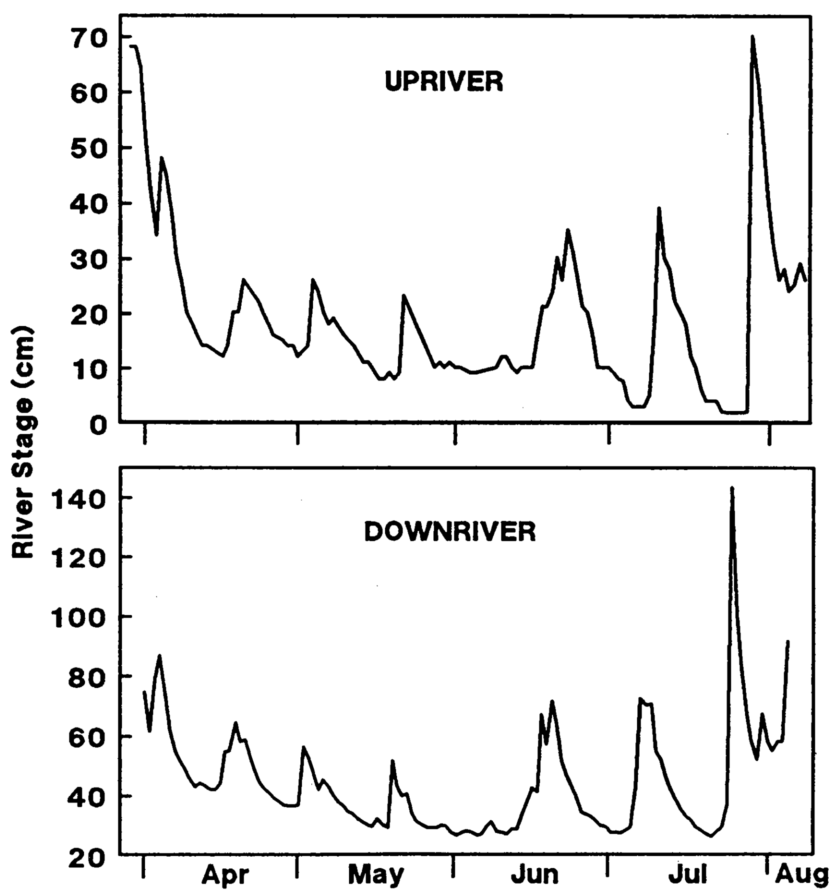

Figure 7.4—River stage of the Situk River at upriver and downriver traps, April to August 1990.

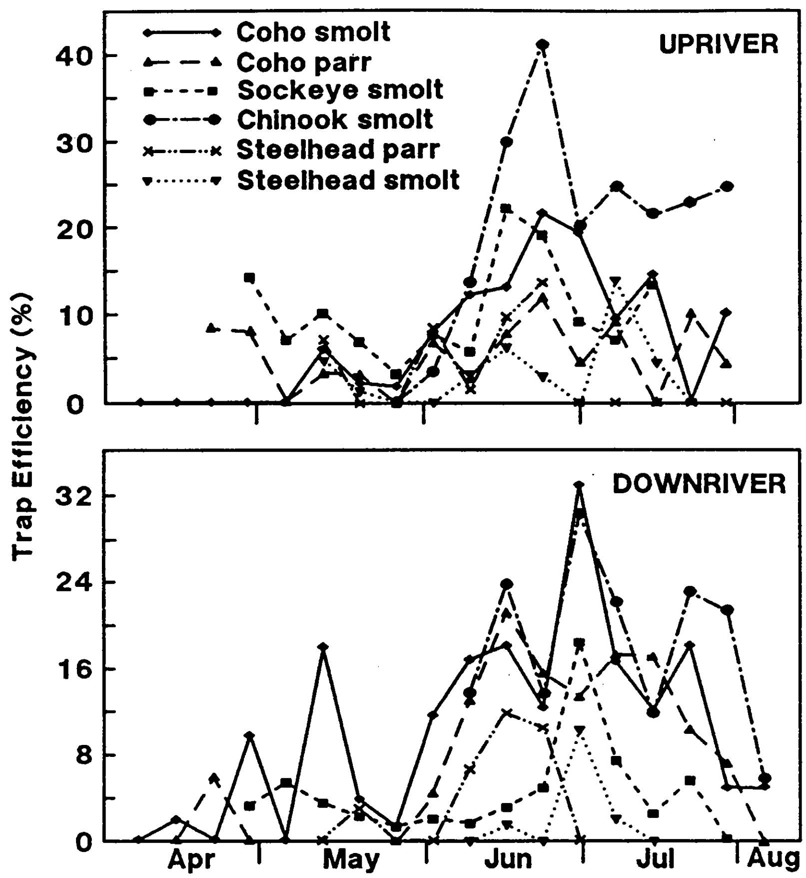

Figure 7.5—Trap efficiency (percentage of marked fish recaptured) for different species and size groups of juvenile salmon from the upriver and downriver traps on the Situk River, April to August 1990.

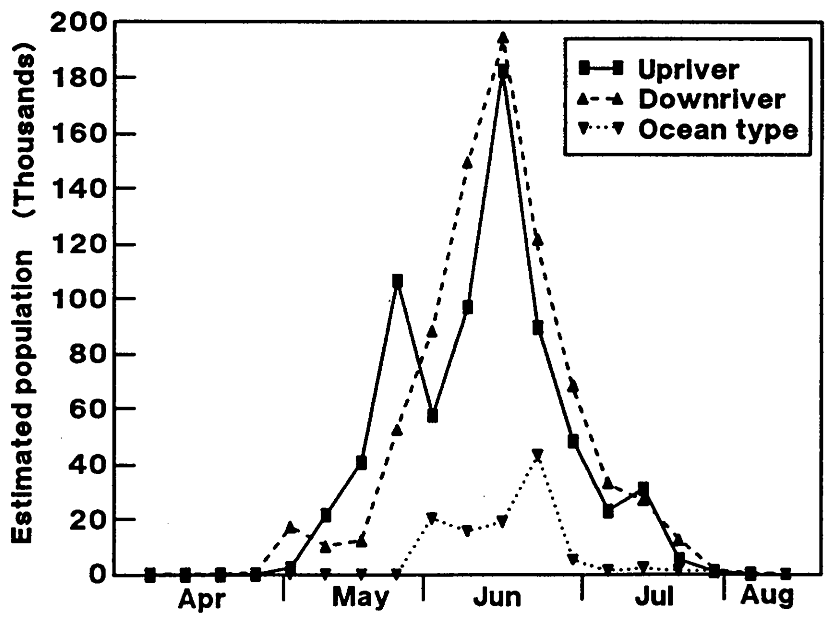

Figure 7.7—Estimated number of sockeye smolts at upriver and downriver and ocean-type sockeye at the downriver traps on the Situk River, April to August 1990.

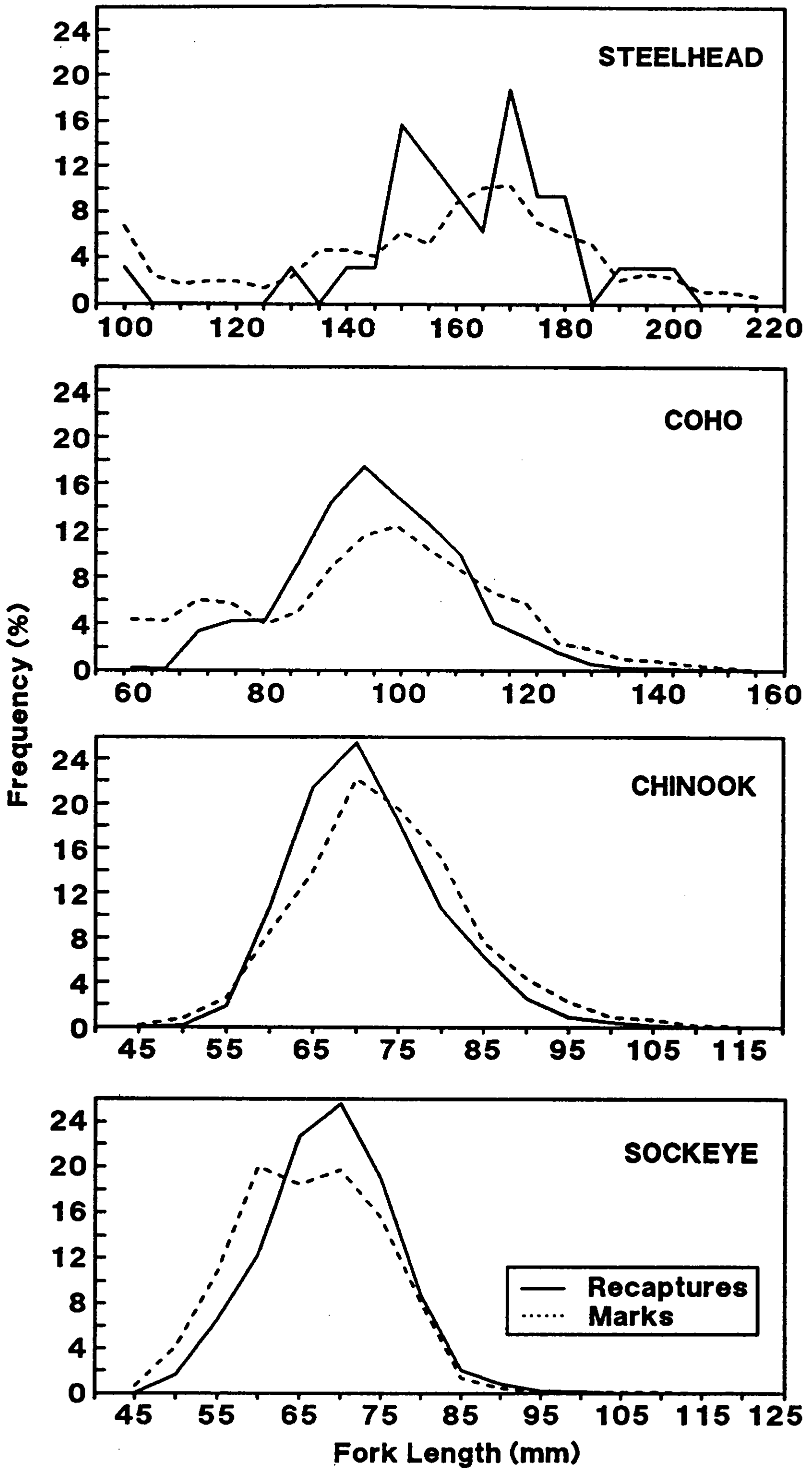

Figure 7.6—Comparison of length frequencies of marked steelhead, coho, chinook, and sockeye smolts released (broken lines) with those subsequently recaptured (solid lines) in the Situk River, April to August 1990.

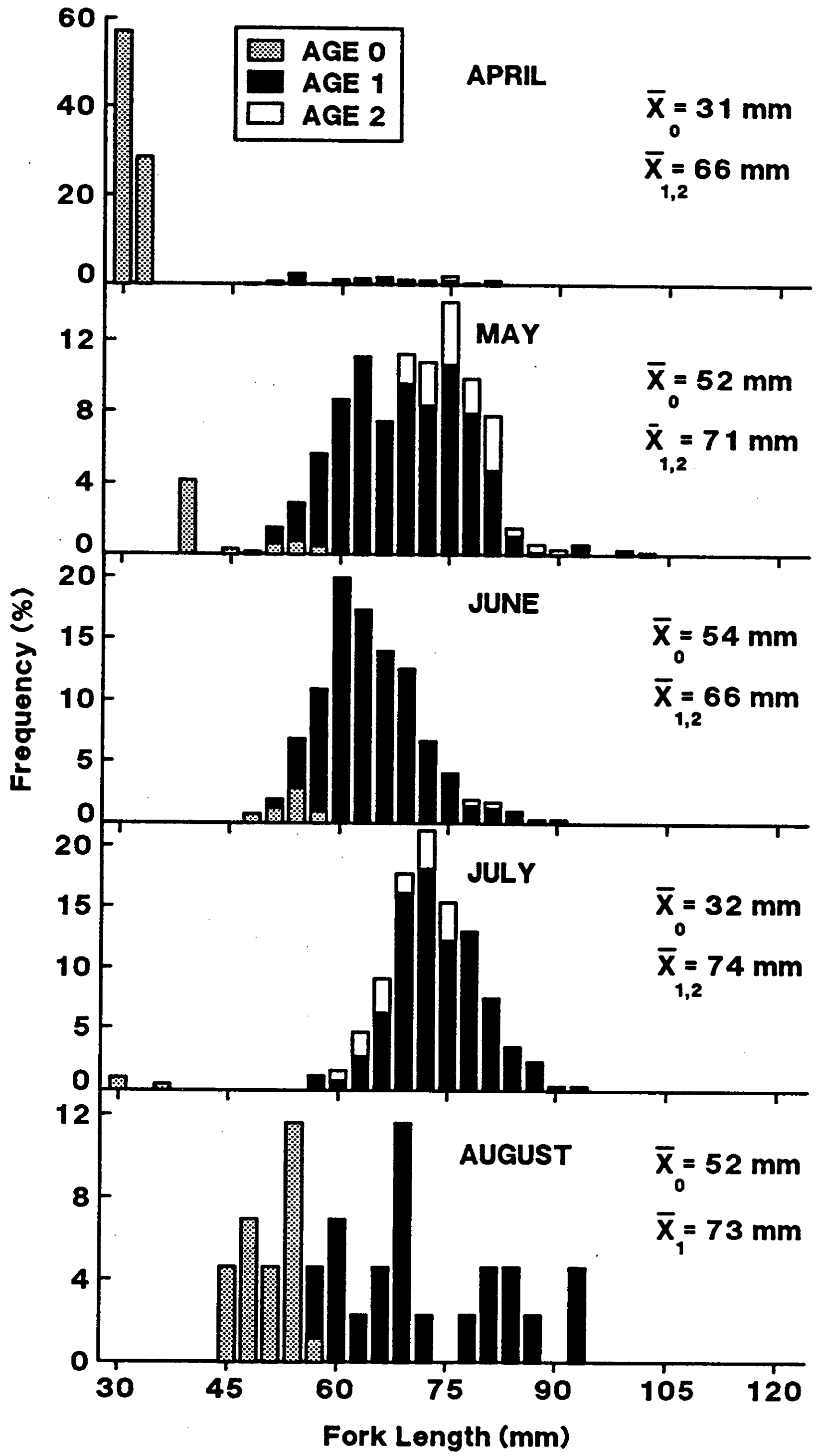

Figure 7.8—Length frequencies and mean length ($\bar{x}$) of juvenile sockeye by age group at the upriver trap in the Situk River, April to August 1990.

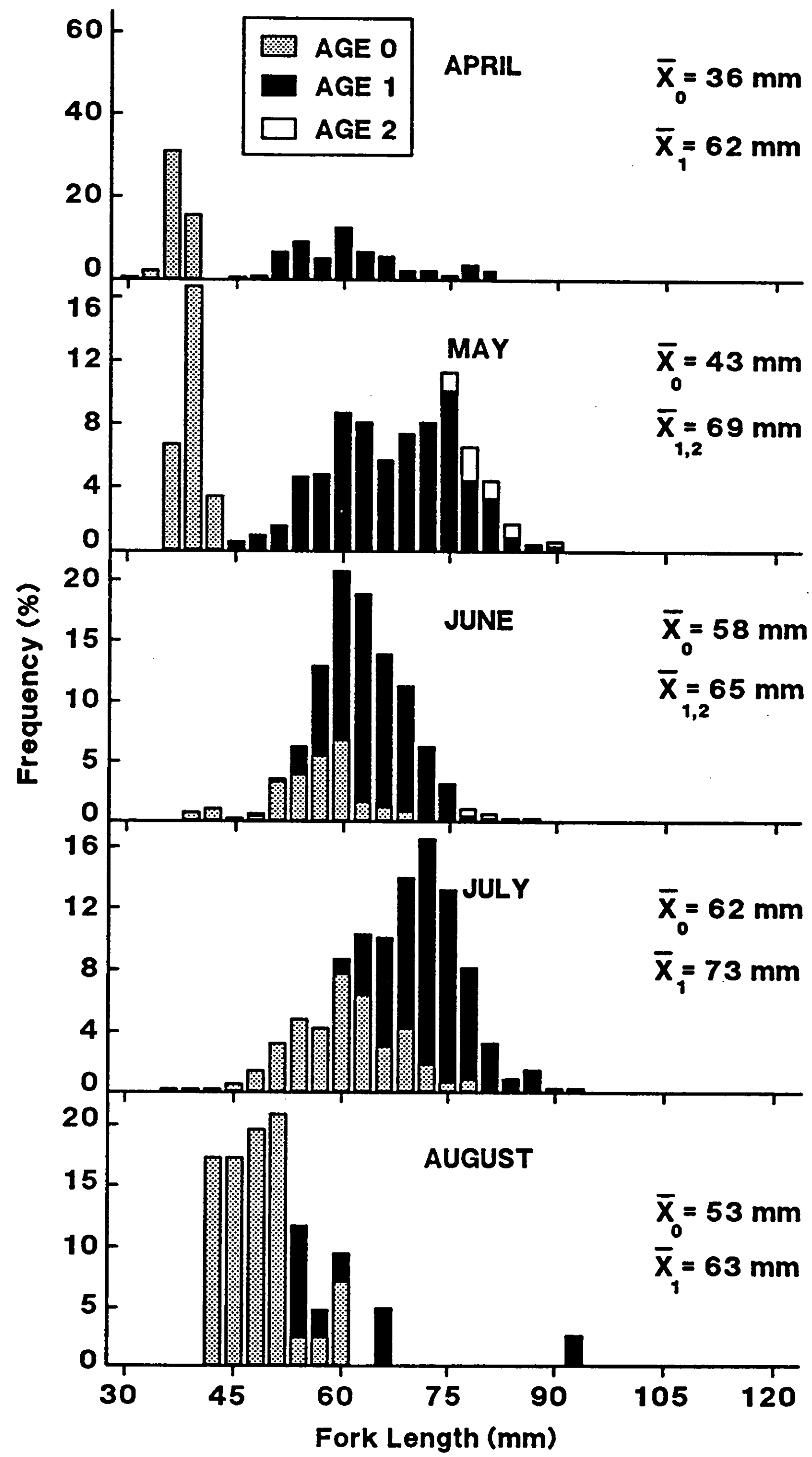

Figure 7.9—Length frequencies and mean length ($\bar{x}$) of juvenile sockeye by age group at the downriver trap in the Situk River, April to August 1990.

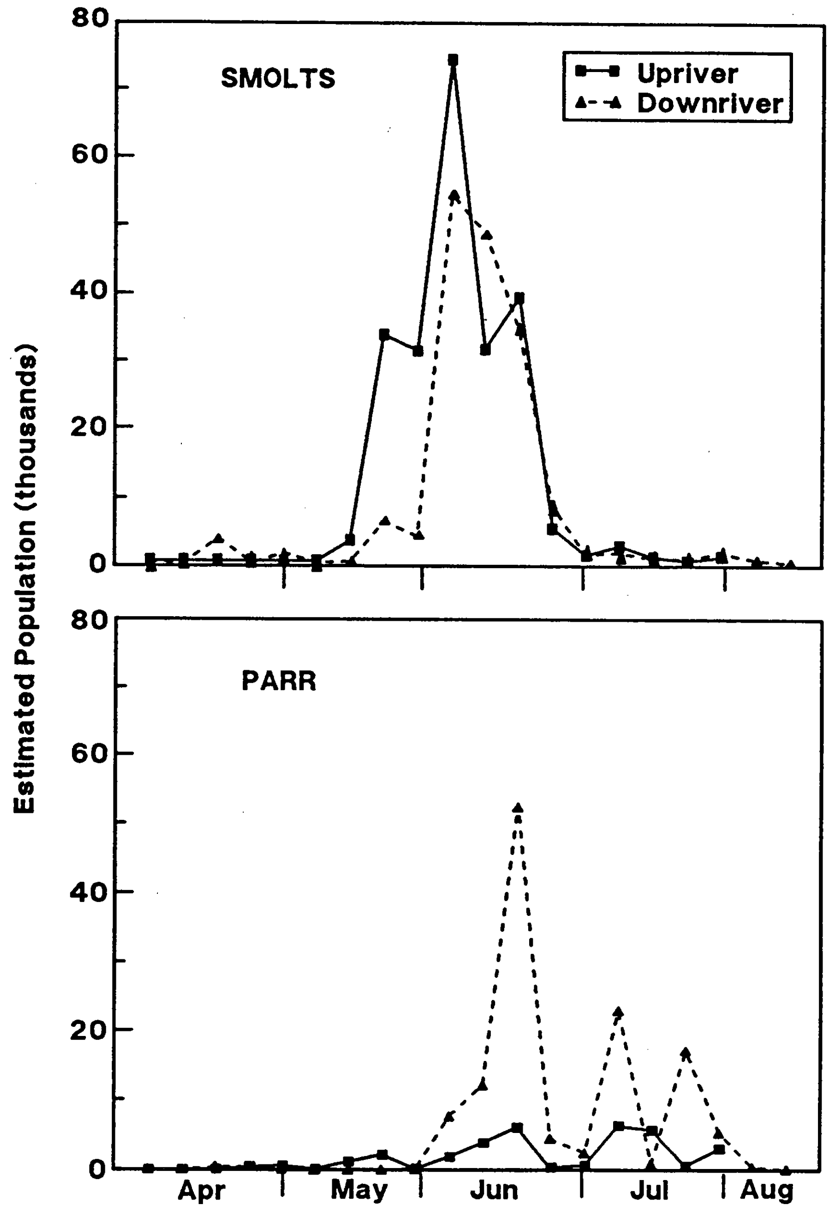

Figure 7.10—Estimated number of coho smolts and parr at upriver and downriver traps on the Situk River, April to August 1990.

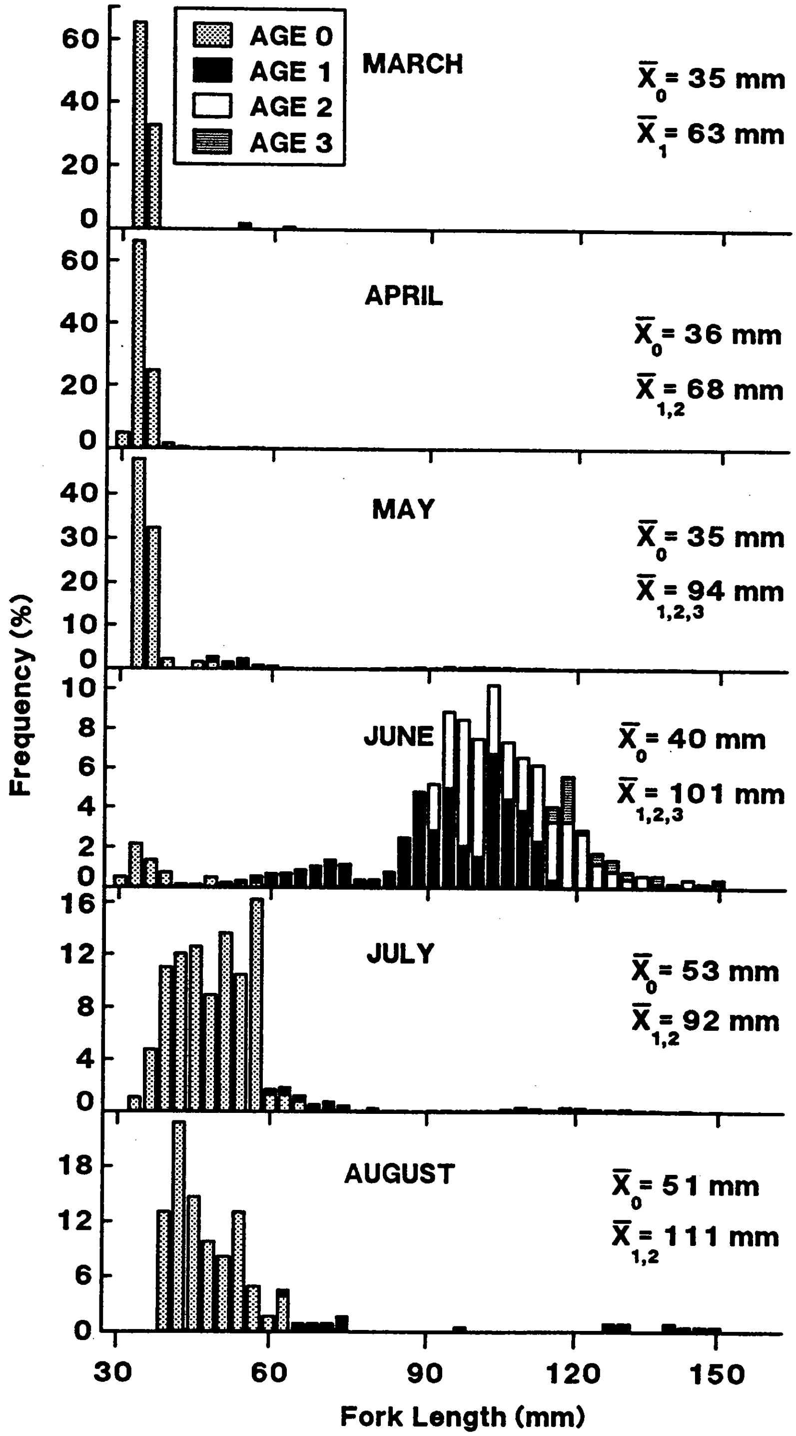

Figure 7.11—Length frequencies and mean length (x̄) of juvenile coho by age group at the upriver trap in the Situk River, April to August 1990.

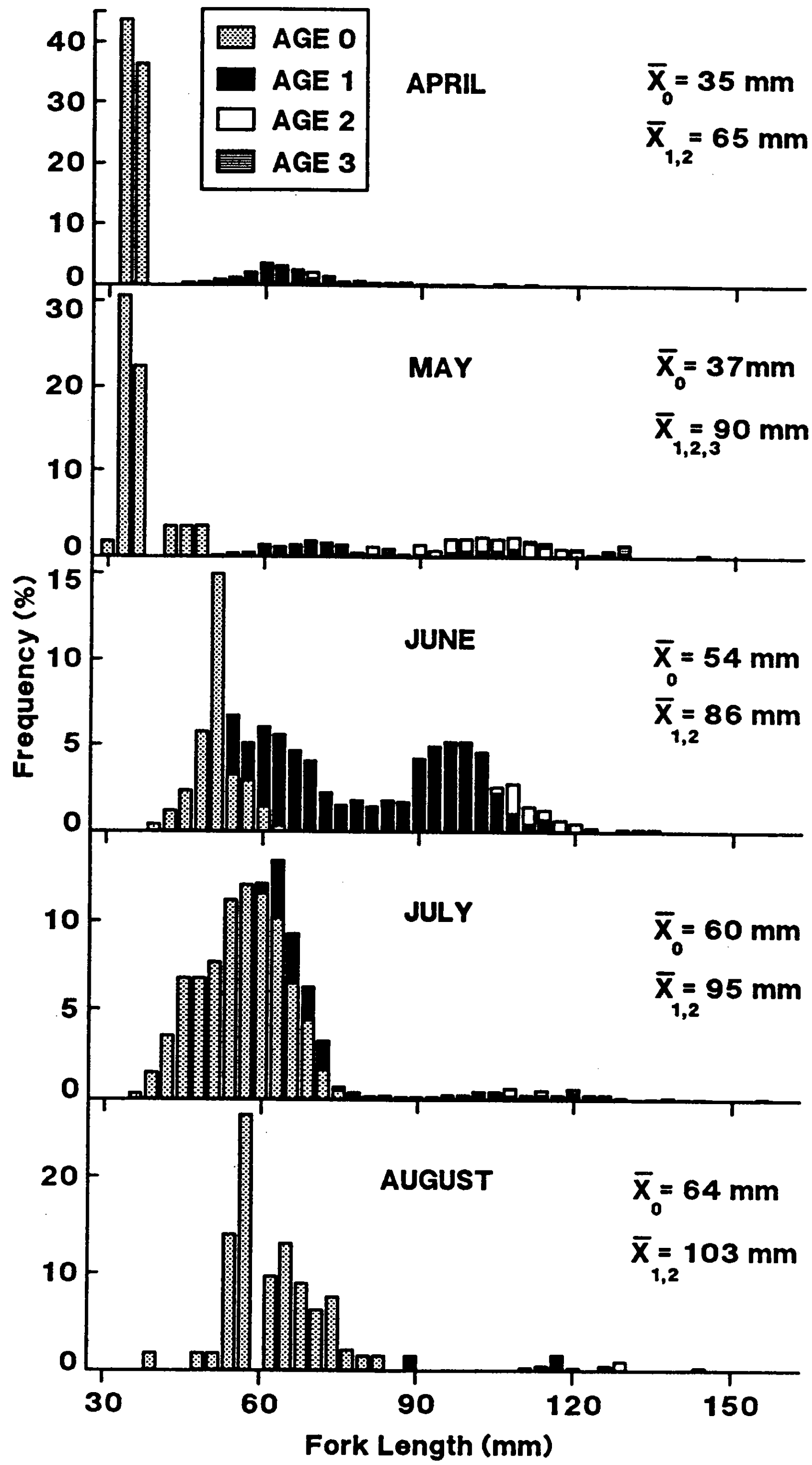

Figure 7.12—Length frequencies and mean length ($\bar{x}$) of juvenile coho by age group at the downriver trap in the Situk River, April to August 1990.

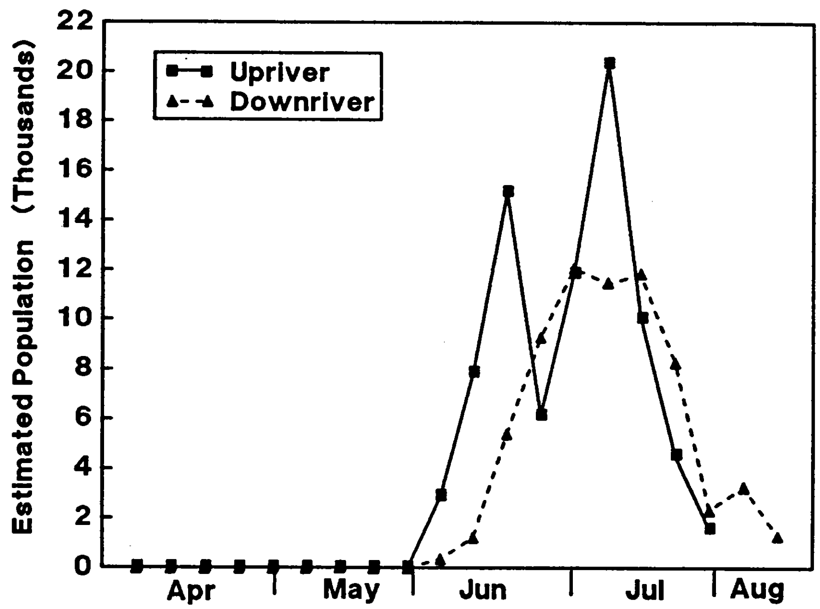

Figure 7.13—Estimated number of chinook smolts at upriver and downriver traps on the Situk River, April to August 1990.

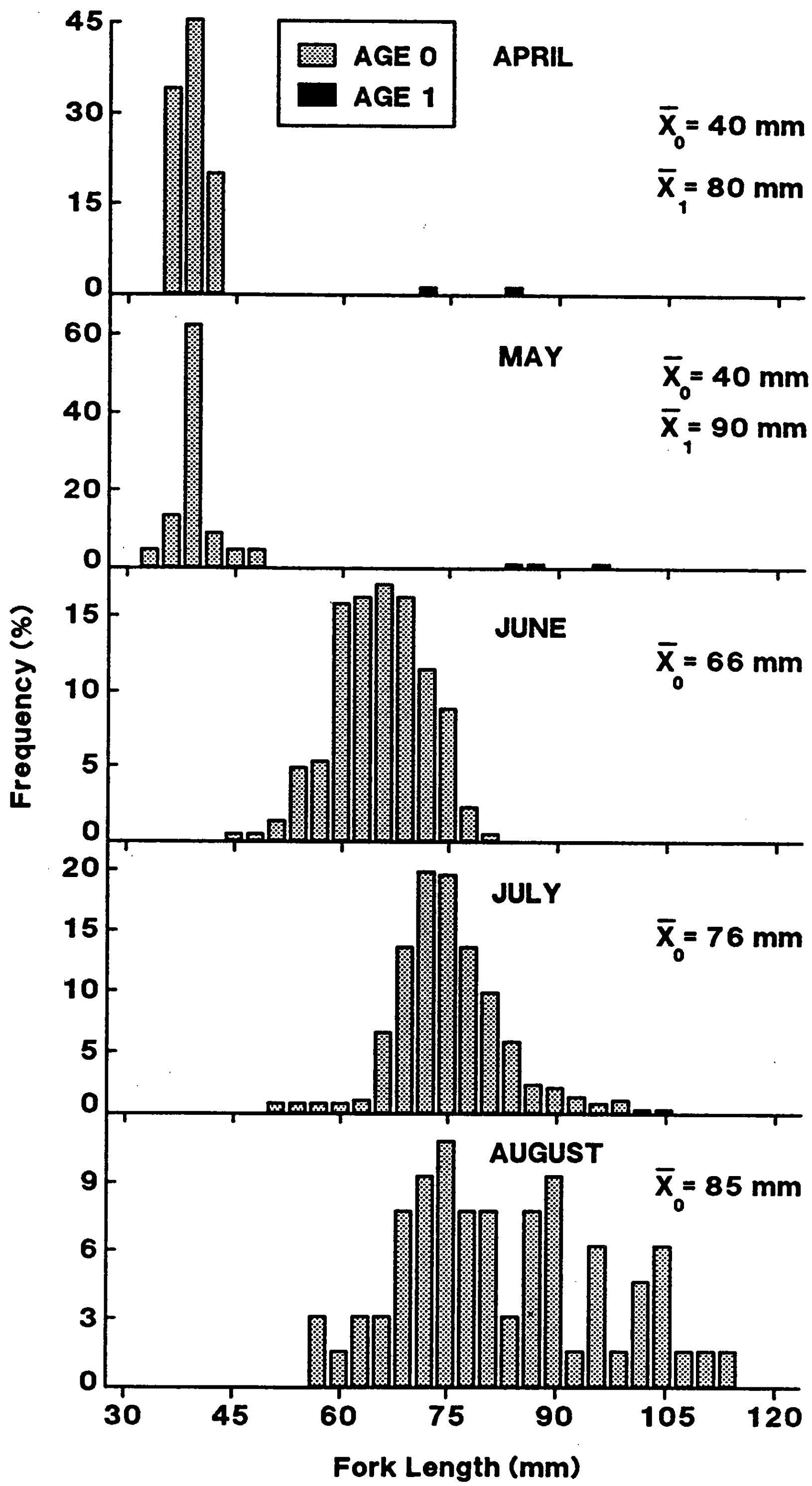

Figure 7.14—Length frequencies and mean length ($\bar{x}$) of juvenile chinook by age group at the upriver trap in the Situk River, April to August 1990.

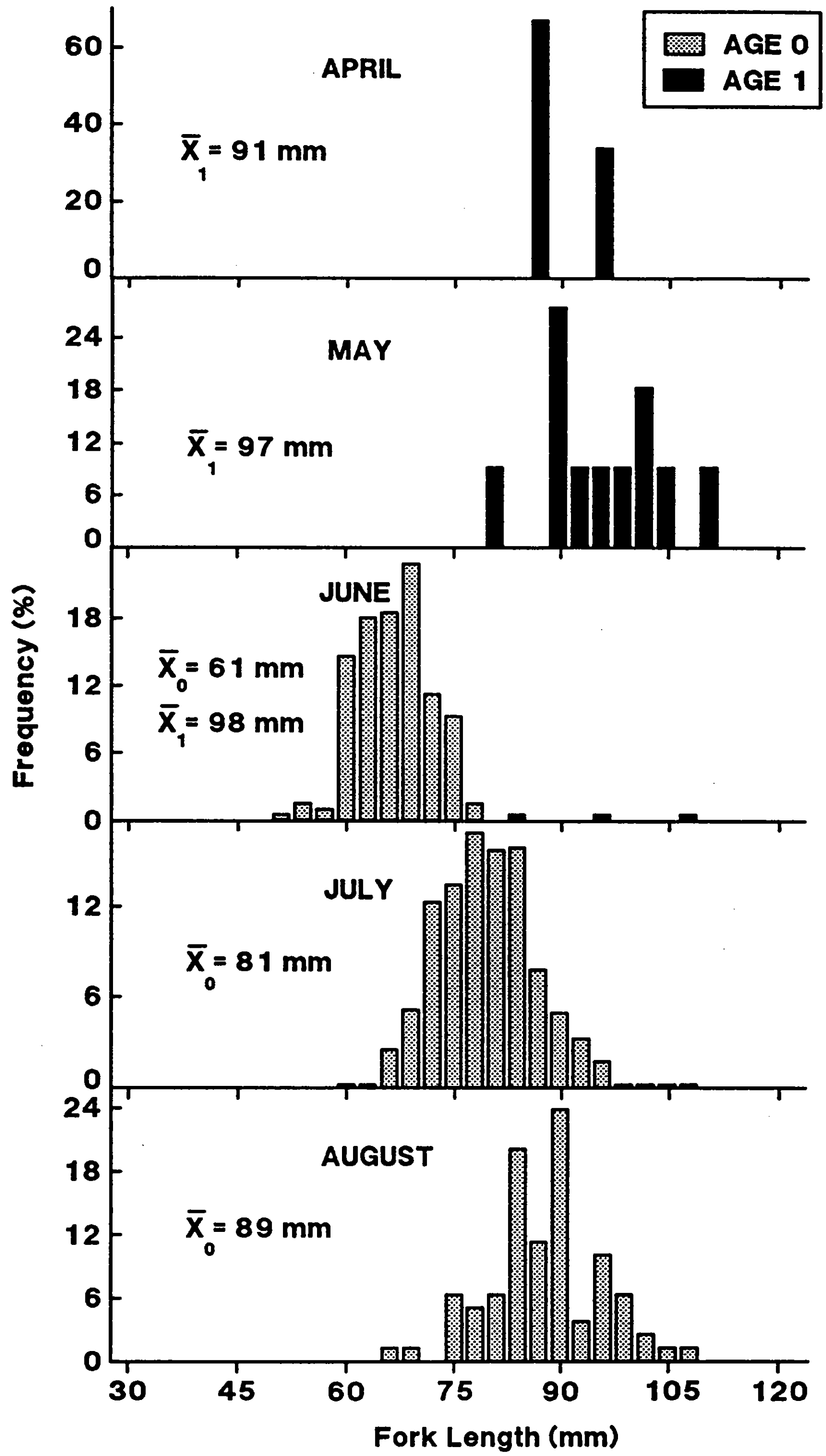

Figure 7.15—Length frequencies and mean length ($\bar{x}$) of juvenile chinook by age group at the downriver trap in the Situk River, April to August 1990.

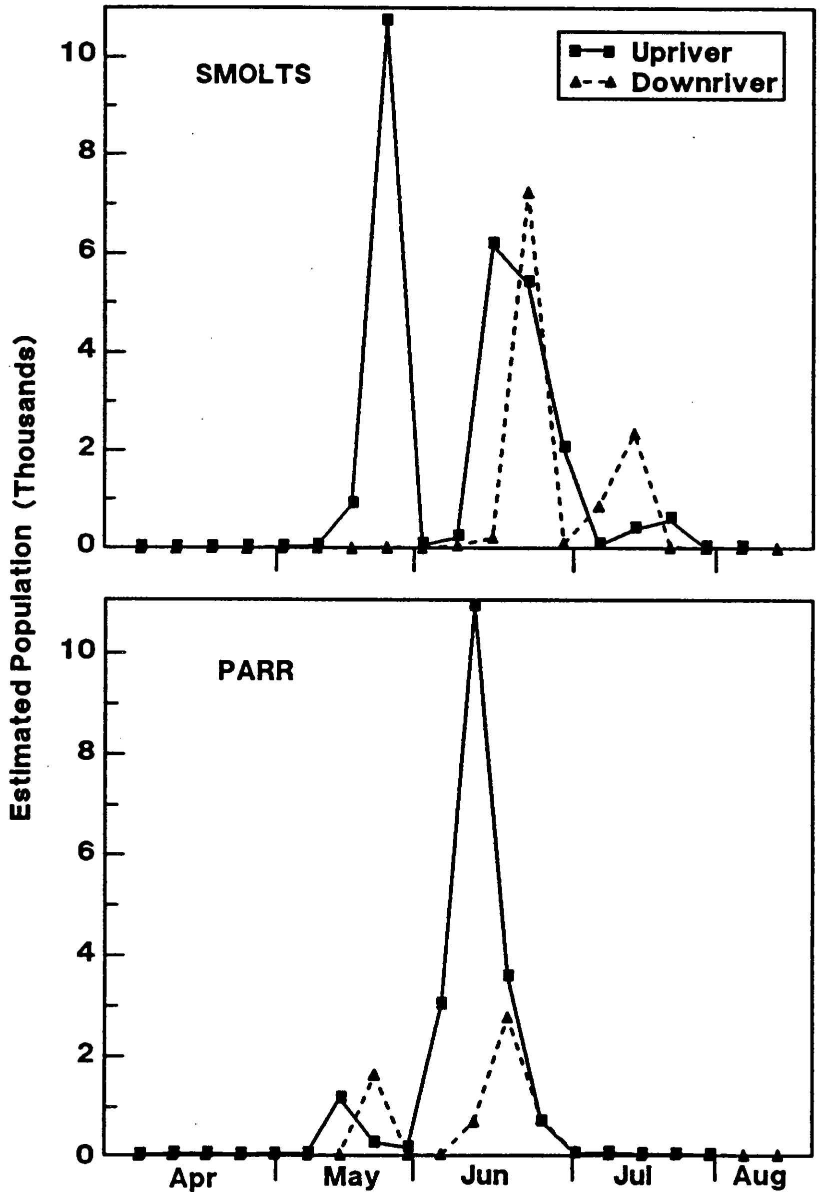

Figure 7.16—Estimated number of steelhead smolts and parr at upriver and downriver traps on the Situk River, April to August 1990.

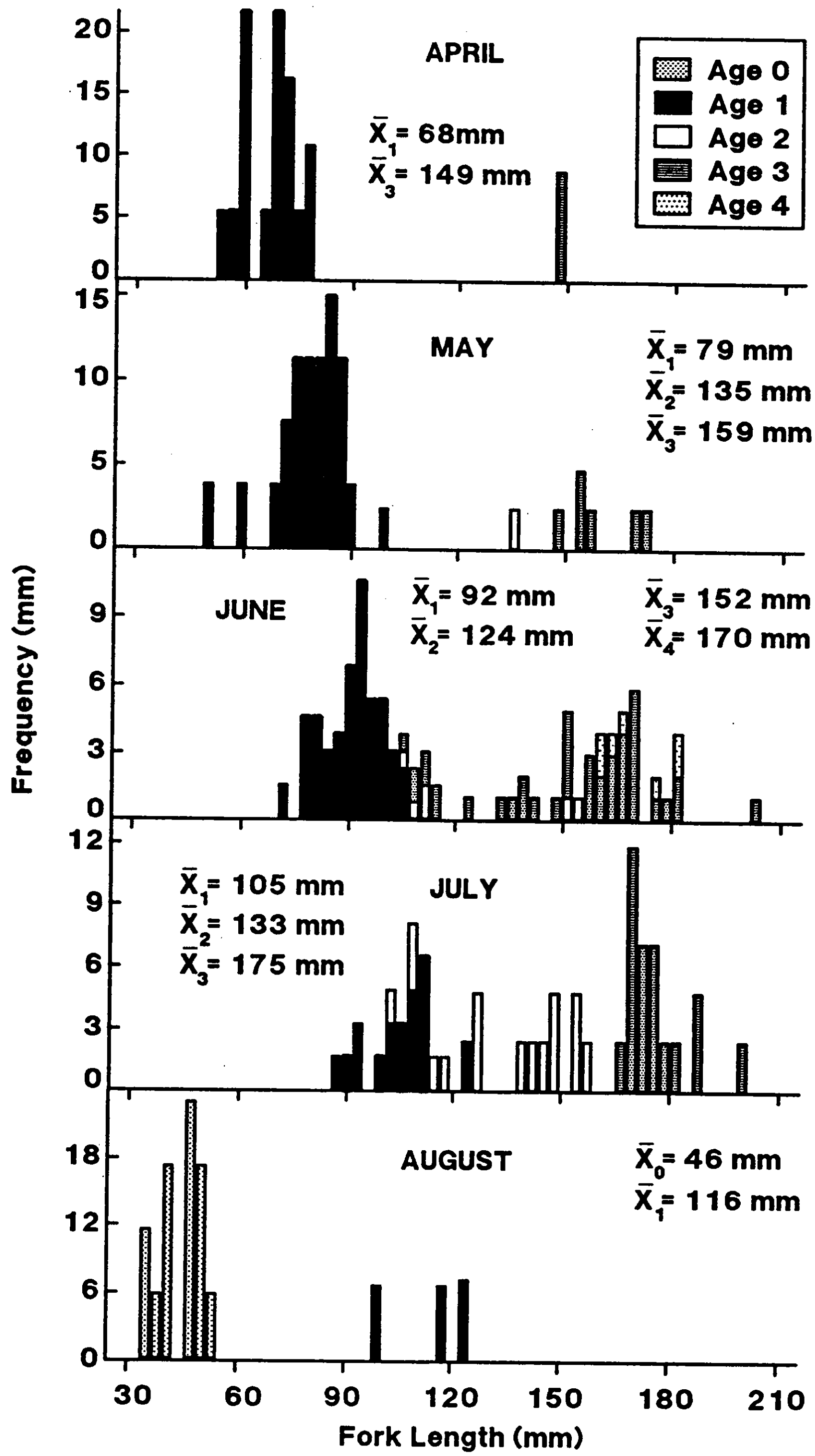

Figure 7.17—Length frequencies and mean length ($\bar{x}$) of juvenile steelhead by age group at the upriver trap in the Situk River, April to August 1990.

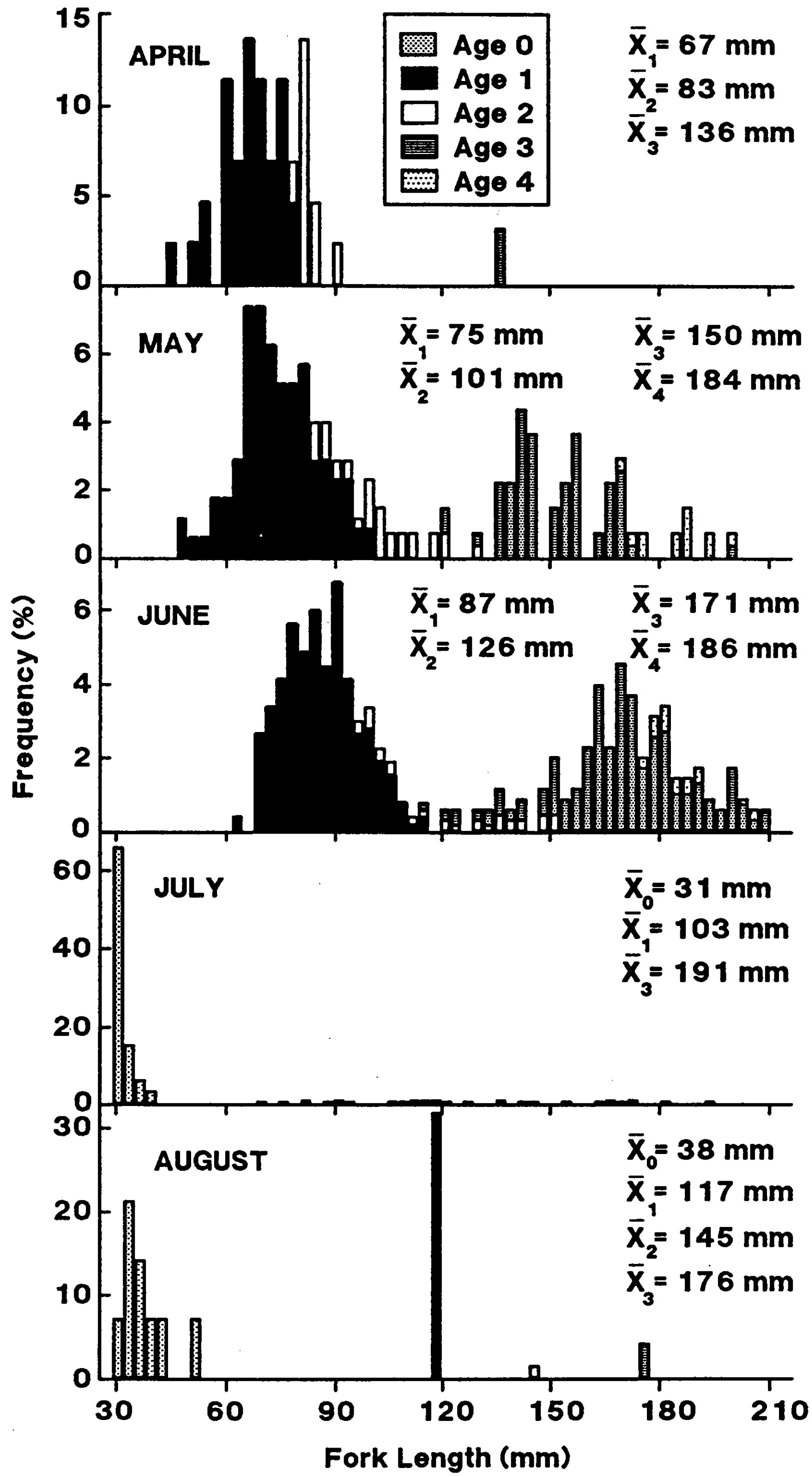

Figure 7.18—Length frequencies and mean length ($\bar{x}$) of juvenile steelhead by age group at the downriver trap in the Situk River, April to August 1990.

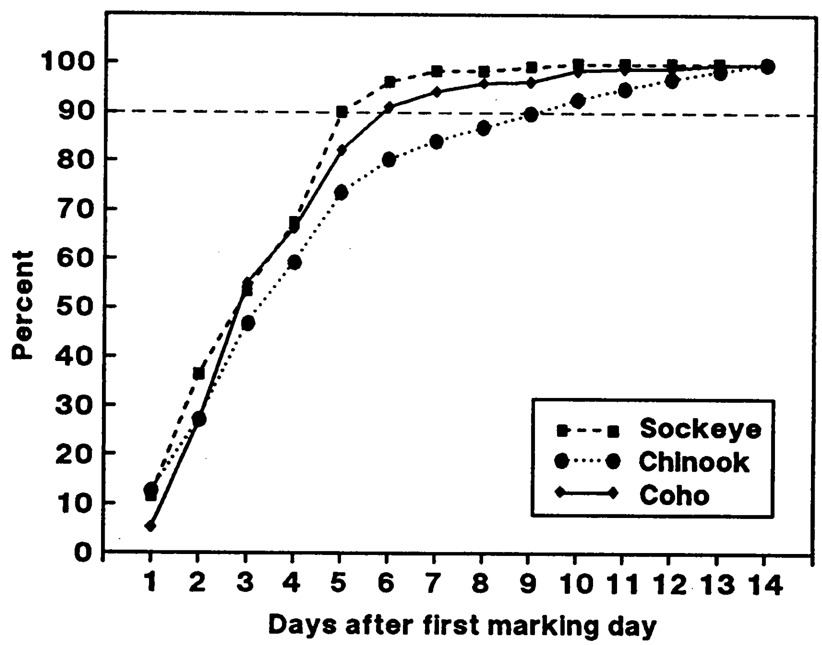

Figure 7.19—Cumulative percentage of recaptures at the downriver trap of marked smolts released at the upriver trap on the Situk River in relation to mean number of days between marking and recapture, April to August 1990.

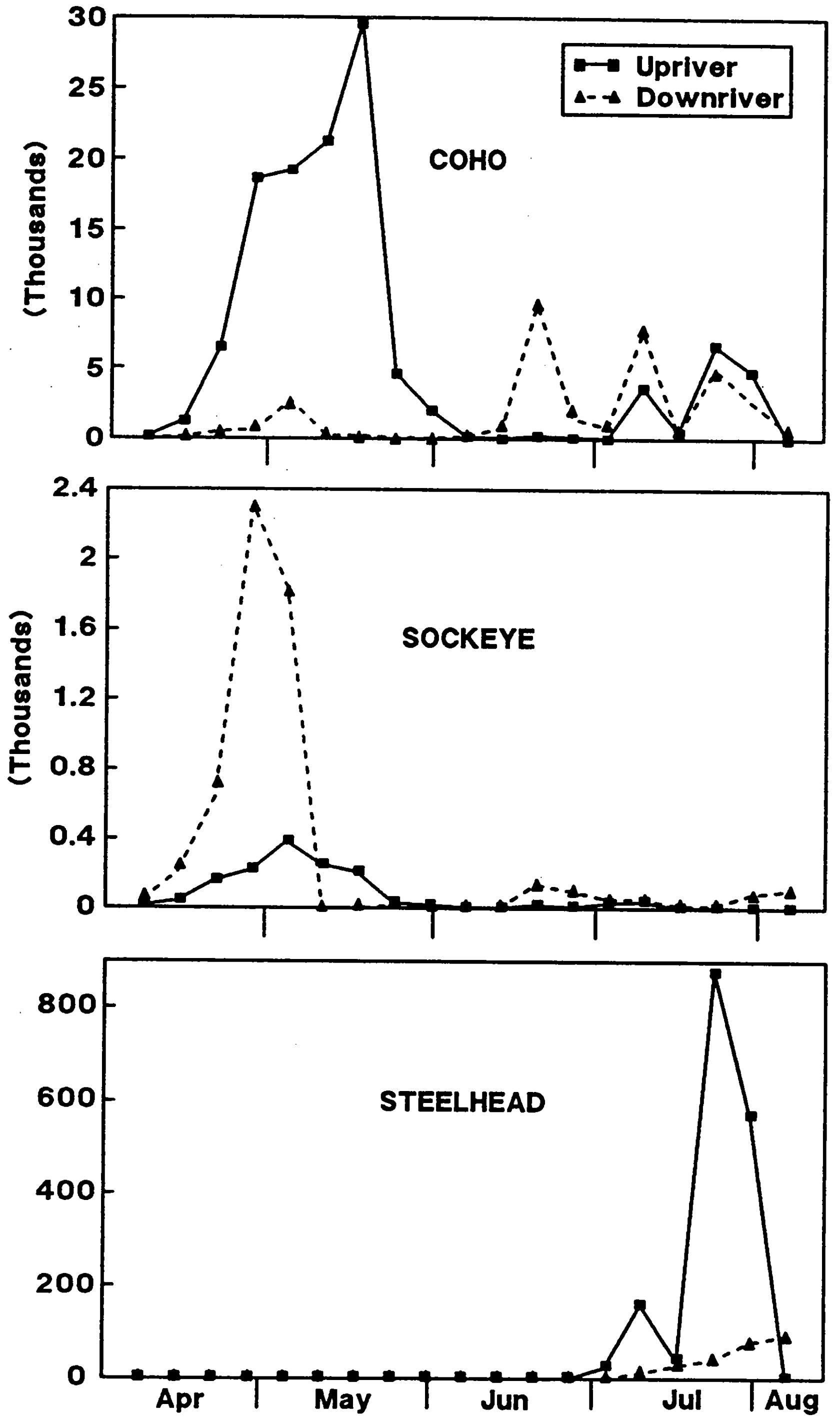

Figure 7.20—Estimated catches of coho, sockeye, and steelhead fry at upriver and downriver traps on the Situk River, April to August 1990.

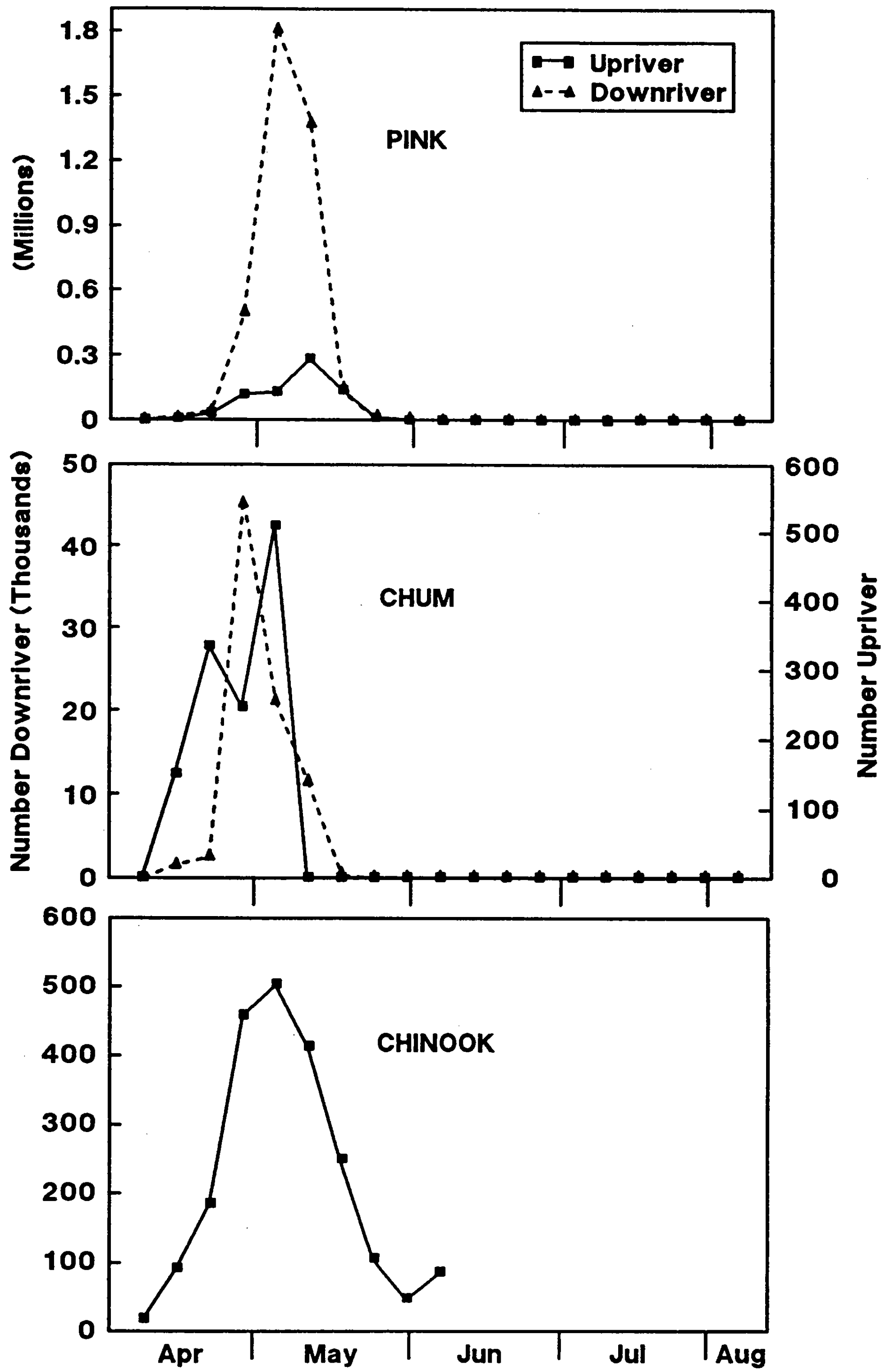

Figure 7.21—Estimated catches of pink, chum, and chinook fry at upriver and downriver traps on the Situk River, April to August 1990.

STUDY 8.

FISH UTILIZATION OF THE SITUK ESTUARY

Rationale

After Hubbard Glacier dams Russell Fiord, overflow from "Russell Lake" could change the Situk estuary. Information on habitat use by fish in the Situk estuary will help to estimate effects of flooding and to determine appropriate restoration strategies.

Objectives

The objectives of this study were to determine the summer abundance and distribution of fish in the Situk estuary.

Summary of Results

Fish were captured in three habitat types in the Situk estuary during spring and summer of 1987 and 1988. The estuary serves as a productive spring and summer rearing area for salmon fry, particularly ocean-type sockeye. The estuary provides habitat for at least 11 species of marine fish and numerous invertebrates, including Dungeness crab. The estuary also is a migration corridor for anadromous fish entering or leaving fresh water.

METHODS

Three habitat types were sampled: 1) "river channels" in the active river channel near the river mouth, 2) "tidal sloughs" in the intertidal *Carex* marshes, and 3) "beaches" in the estuary basin. One to three sites (Fig. 8.1) of each habitat type were sampled each month from April (May in tidal sloughs) to August in 1987 and from March to July (August in tidal sloughs) in 1988. Temperature and salinity were measured periodically in each tidal slough and beach site. Sampling methods differed among habitat types. At each river channel and beach site, fish abundance was indexed by catch per unit effort. Three separate areas, 20-50 m apart, were sampled with a beach seine that was 28 m long and 3 m deep, with wings of 13-mm mesh and a central bag of 6-mm mesh (Fig. 8.2). The seine was set with a skiff parallel to and 40 m from shore and pulled to shore with ropes. In tidal sloughs, fish density was estimated by the removal method (Zippin 1958). A 30-m section of slough was enclosed with 6-mm-mesh nets and repeatedly seined (≥3 times) with a pole seine (Study 2). Width of the slough section was measured at 3-m intervals, and fish density was calculated by dividing the population estimate by the section area.

Captured salmonids were tranquilized with dilute MS-222, identified, and measured for FL. Scale samples were taken from a representative size range (except Dolly Varden) to determine age. Non-salmonids were identified, counted, and released.

RESULTS

Results presented here from 1987 pertaining to habitat characteristics and sockeye have been published elsewhere (Heifetz et al. 1989), and some 1988 results pertaining to sockeye are also summarized in Study 5.

Fish catches in the river channel usually were dominated by sockeye salmon, staghorn sculpins, and starry flounders (Tables 8.1, 8.2). Other salmonids except pink salmon in May 1987 and adult Dolly Varden (about 200 mm FL) in June 1987 were uncommon. Other nonsalmonids (sticklebacks, eulachon, and Pacific sand lance) were captured only in May 1987 and were uncommon.

In tidal sloughs, fish assemblages were dominated by sockeye fry, coho fry, staghorn sculpins, and sticklebacks (Tables 8.3, 8.4). Chinook, pink, and chum fry were less abundant than coho and sockeye fry and were primarily captured in March and April. Age-1 coho presmolts were present in May and June and were most abundant in early June.

In beach habitat, catches were dominated by Pacific sand lance, starry flounders, and sockeye salmon fry, but several other species also were caught (Tables 8.5, 8.6). Pink fry were common in May, chum fry were common in April, and coho and chinook fry were uncommon. Salmonid smolt catches were generally low (mean, 1-3 smolts per seine haul) and adult Dolly Varden were common in May. For nonsalmonids, larval eulachon were abundant in March and juvenile Dungeness crab were present from May to August.

Salmonid fry were abundant in the estuary, particularly in tidal sloughs. Sockeye fry were the most abundant salmonid; their density in tidal sloughs averaged over 1,200 per 100 m^2 in April 1988 (Table 8.4; Fig. 8.3). Sockeye present in March and April were newly emerged fry, averaging 32 mm FL (Figs. 8.4, 8.5). Mean FL of sockeye fry in tidal sloughs increased to nearly 50 mm in June. Although mean FL increased rapidly, small (<40 mm) sockeye were always present. In July 1987, for example, size ranged from less than 40 mm to over 90 mm FL. Density in tidal sloughs declined sharply in May and remained low the rest of the summer. After density declined in tidal sloughs, numbers temporarily increased in beach and river channel habitats in June and declined sharply thereafter. Ocean-type sockeye are covered in further detail in Study 5.

Coho fry were present in the estuary from March to August, primarily in tidal sloughs (Fig. 8.6). Density in all three habitat types peaked in June and declined sharply in July. Coho in May were primarily newly emerged fry with a mean FL of 39 mm (Fig. 8.7). Mean FL increased during the summer, but newly emerged fry were always present. Mean FL increased to about 50 mm (range, 39-72 mm) in June and 55 mm in July (range, 33-70 mm).

In 1988, chinook fry were present in the estuary from March to mid-July. Abundance in tidal sloughs followed a different pattern from that in the river channel or beaches (Fig. 8.8). In tidal sloughs, density peaked in April; in river channels and beaches, catches peaked twice, in May and again in July. In March and April, captured chinook were primarily newly emerged fry, ranging from 38 to 44 mm FL (Fig. 8.9). In late May, chinook FL increased to a range of 44-57 mm FL. Ocean-type chinook are covered further in Study 4.

Salmonid smolts (age ≥1) were present in the estuary for a shorter time than salmonid fry. Smolts were in the estuary in May, June, and July. Peak abundance was in May and numbers declined sharply during June (Fig. 8.10). Peak density in tidal sloughs was in June, about 1 month later than in other habitats, because coho pre-smolts immigrated into the sloughs in June.

Adult Dolly Varden were numerous along estuary beaches and in the river channel for short periods, but were absent from tidal sloughs (Tables 8.1, 8.6; Fig. 8.11). Adult Dolly Varden were caught in estuary beaches in May, in the river channel in June, and then probably moved upstream into the main-stem river in July, as only one adult Dolly Varden was caught in the estuary after June.

Juvenile Dungeness crab also were caught in estuary beaches, primarily low-gradient sandy beaches off Blacksand Spit (Fig. 8.1). Peak catch of crab (5 crab per seine haul) was in May in 1987 (Table 8.5) and in June in 1988 (Table 8.6). In June 1988, crab carapace length averaged 58 mm, and ranged from 25 to 100 mm.

Water temperature in tidal sloughs increased from about 2-4°C in March and April to 22°C in July (Table 8.7). Water temperature in estuary beaches was lower in June than in the tidal sloughs. Salinity was generally low in tidal sloughs, ranging from 0 to 15‰, and moderate in estuary beaches, ranging from 18 to 26‰ (Table 8.7).

DISCUSSION

The Situk estuary contains productive habitat for juvenile salmonids and other fishes and invertebrates. The tidal sloughs along the estuary margins are particularly important for salmonid fry in spring. Tidal sloughs form essential habitat for the uncommon ocean-type sockeye which migrates to the estuary in March as newly emerged fry and uses tidal sloughs to grow large enough to survive in seawater (Study 5). The southwest aspect of the tidal marshes allows early warming in spring, when many salmon fry emerge and colonize habitats. For example, water temperature in the tidal sloughs in mid-May was about 10°C, compared to about 3-8°C in the main-stem Situk River (see Study Area, Fig. H.6). Relatively high water temperature and low salinity (0-15‰) make tidal sloughs suitable for salmon fry and allow rapid growth and gradual adaptation to seawater.

The estuary serves as a migration corridor for salmonid adults and smolts, as well as eulachon adults and larvae. None of these life stages, however, apparently spends much time in the estuary. Salmon smolts migrated quickly through the estuary. Although several million smolts were estimated to migrate through the estuary (Study 7), few smolts were caught there. Smolts did not use tidal sloughs, even though coho pre-smolts and large numbers of salmonid fry used them. Most smolts probably distributed pelagically, away from the beaches, as they migrated through the estuary.

The Situk estuary provides habitat for a number of stocks from adjoining streams and rivers. Several other salmon-producing streams, including Kunayosh Creek, Seal Creek, and the glacial Ahrnklin River (Fig. 8.1), also flow into the estuary. Thus, some fish residing in the estuary may have originated from streams other than the Situk River.

Table 8.1—Mean catch of all species per seine haul in the river channel, Situk estuary, April to August 1987. Zero values are omitted. Number of sites sampled is in parentheses.

Species	Stage	21 Apr (1)	20 May (2)	17 Jun (2)	26 Jul (2)	8 Aug (1)
Sockeye	fry	4.1	10.8	12.7		
	smolt		14.2	3.3		
Coho	fry			1.7		
	smolt			1.0		
Chinook	fry			0.7	1.7	
Pink	fry	1.7	9.9			
Chum	fry		1.0			
Steelhead	smolt			0.3		
Dolly Varden	adult			16.3		
Staghorn sculpin	all stages		11.0		12.8	10.0
Stickleback	all stages		1.0			
Starry flounder	all stages		22.0	10.8	67.8	10.0
Sand lance	adult		5.8			
Eulachon	adult		1.0			

Table 8.2—Mean catch of all species per seine haul in the river channel of Situk estuary, March to July 1988. One site was sampled each month. Zero values are omitted.

Species	Stage	15 Mar	12 Apr	31 May	23 Jun	13 Jul
Sockeye	fry	10.3	6.3		0.7	1.0
	smolt			1.0	1.7	
Coho	fry		0.3			
	smolt			0.3	4.3	
Chinook	fry	1.0	0.3			1.0
	smolt			0.3		
Pink	fry	0.7	0.3			
Dolly Varden	adult				1.7	
Starry flounder	all stages			1.0		

Table 8.3—Mean density (no./100 m²) of all fishes from tidal sloughs in the Situk estuary, May to August 1987. Zero values are omitted. Number of sites sampled is in parentheses.

Species	Stage	20 May (1)	17 Jun (3)	26 Jul (3)	8 Aug (2)
Sockeye	fry	12.8	0.4	0.1	0.1
Coho	fry	35.2	69.1	21.0	9.8
	smolt*	4.4	9.8	1.1	
Chum	fry	2.2			
Sculpin	adult	42.9	49.4	47.7	
Stickleback	all stages	56.1	212.3		
Starry flounder	all stages	2.2	1.3	4.6	

*Most age-≥1 coho from tidal sloughs were "pre-smolts," with faint parr marks and silvery sheen to scales.

Table 8.4—Mean density (no./100 m^2) of all fishes in tidal sloughs in the Situk River estuary, March to July 1988. Two sites were sampled each month, except 13 May, 29 July, and 31 August, when one site was sampled. No fish were caught in August. Zero values are omitted.

Species	Stage	14 Mar	11 Apr	13 May	1 Jun	20 Jun	13 Jul	29 Jul
Sockeye	fry	737.5	1226.8	84.2	71.8	14.7	3.2	1.2
	smolt	0.6						
Coho	fry	4.2	7.8	10.8	66.7	73.4	39.8	48.1
	smolt*			3.6	17.3	2.9		
Chinook	fry	3.6	19.3		5.8			
Pink	fry		8.4					
Chum	fry	9.6	7.2					
Sculpin	all stages		110.6	39.7	19.9	20.0	40.0	
Stickle-back	all stages		40.0	49.0	24.7	27.9	50.0	

*Most age-≥1 coho from tidal sloughs were "pre-smolts," with faint parr marks and silvery sheen to scales.

Table 8.5—Mean catch of all species per seine haul from beaches in Situk estuary, April to August 1987. Seven sites were sampled each month. Zero values are omitted.

Species	Stage	21 Apr	20 May	17 Jun	26 Jul	8 Aug
Sockeye	fry	11.2	0.3	23.5	0.4	
	smolt		0.7	0.3	1.3	
Coho	fry	0.7		2.0		
	smolt		3.4	1.7	0.7	
Chinook	fry		0.7	0.3	1.0	
Pink	fry	9.4	23.0			
Chum	fry	14.7	0.7	0.3		
Dolly Varden	adult		22.5			0.3
Sculpin	all stages		1.5	2.0	7.3	3.7
Stickleback	all stages		2.0			
Starry flounder	all stages		23.7	15.2	63.1	47.7
Eulachon	adult	0.7	83.1	4.0	0.3	
Pacific sand lance	adult			112.2	1000.0	50.0
Prickle-back	adult			1.0	3.4	
Sand sole	adult			0.8	1.3	1.2
Herring	juv.				1.0	2.0
Greenling	adult				2.0	0.3
Dungeness crab	juv.		4.8	0.5	1.9	1.3

Table 8.6—Mean catch of all species per seine haul from beaches in the Situk estuary, March to July 1988. Two sites were sampled each month except May and June. Zero values are omitted. No salmonids were caught in July.

Species	Stage	15 Mar	12 Apr	31 May	23 Jun
Sockeye	fry	3.0	3.5		0.7
	smolt			0.3	
Coho	smolt			0.7	
Chinook	fry		0.2		
Pink	fry	1.0			
Dolly Varden	adult			1.0	
Sculpin	all stages		1.2	2.3	1.7
Starry flounder	all stages	4.3	6.2	2.7	4.0
Arrowtooth flounder	juv.				3.7
Pacific sand lance	adult	51.7			82.0
Eulachon	larvae	135.0			
	adult		0.2	2.0	
Smelt	adult			2.3	0.7
Dungeness crab	juv.				5.0

Table 8.7—Mean water temperature (°C) and salinity (‰) in tidal sloughs and estuary beaches in the Situk estuary, March to July 1988. A dash indicates no data.

	Tidal slough		Estuary beach	
Date	Temp.	Salinity	Temp.	Salinity
14 March	4.4	5.0	—	26.0
11 April	2.5	0.0	4.3	17.5
13 May	10.5	0.4	—	—
1 June	16.8	13.0	10.8	26.0
20 June	19.8	—	—	—
11 July	22.5	15.0	—	—

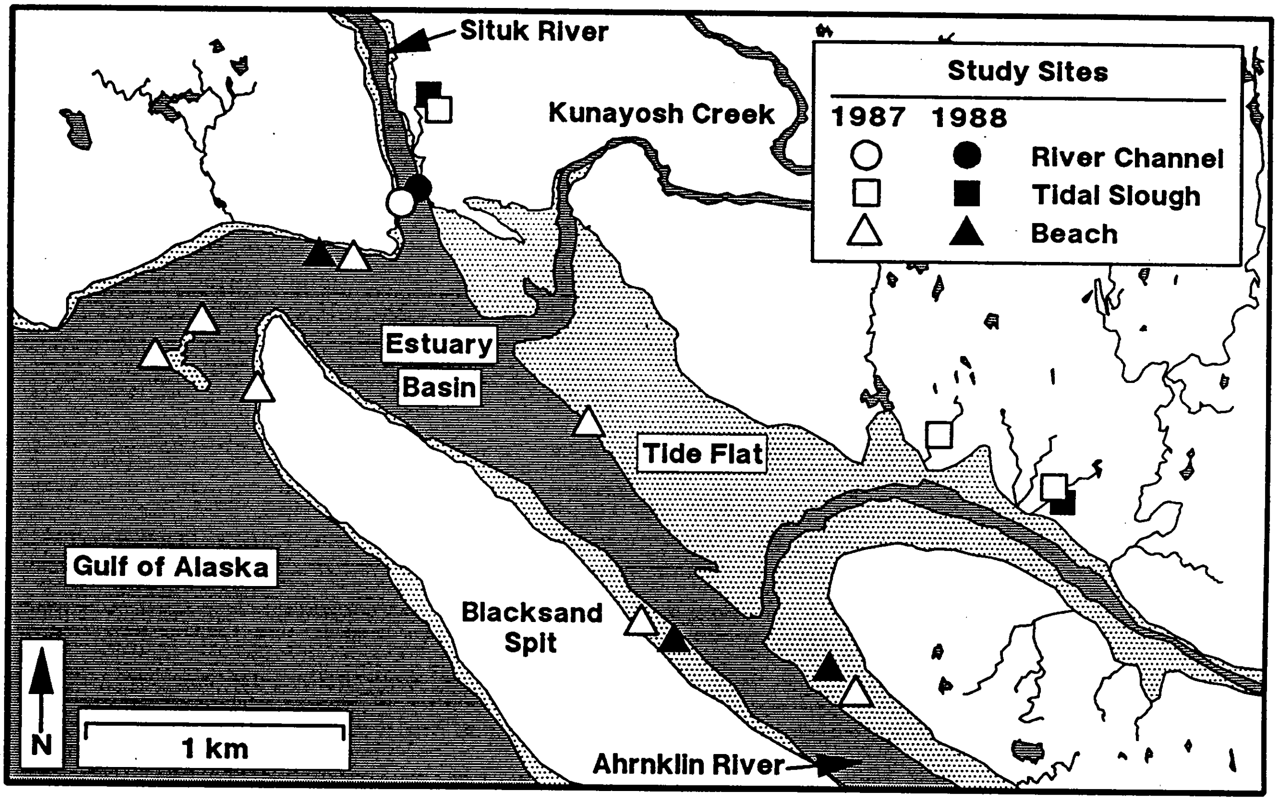

Figure 8.1—Map of Situk estuary, showing location of sampling sites.

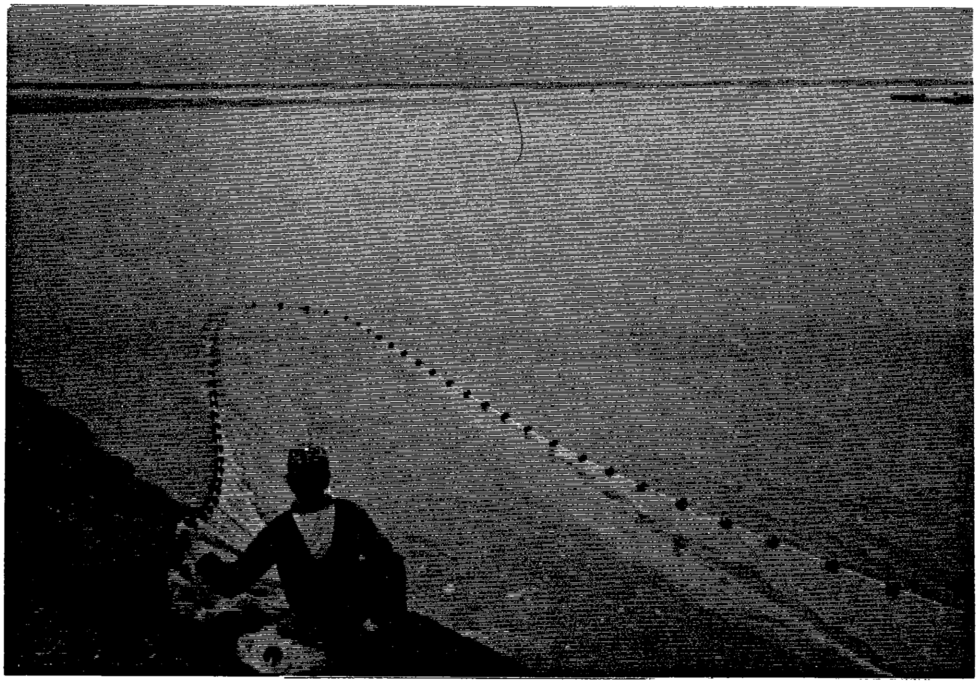

Figure 8.2—Seining in the Situk estuary basin, July 1988.

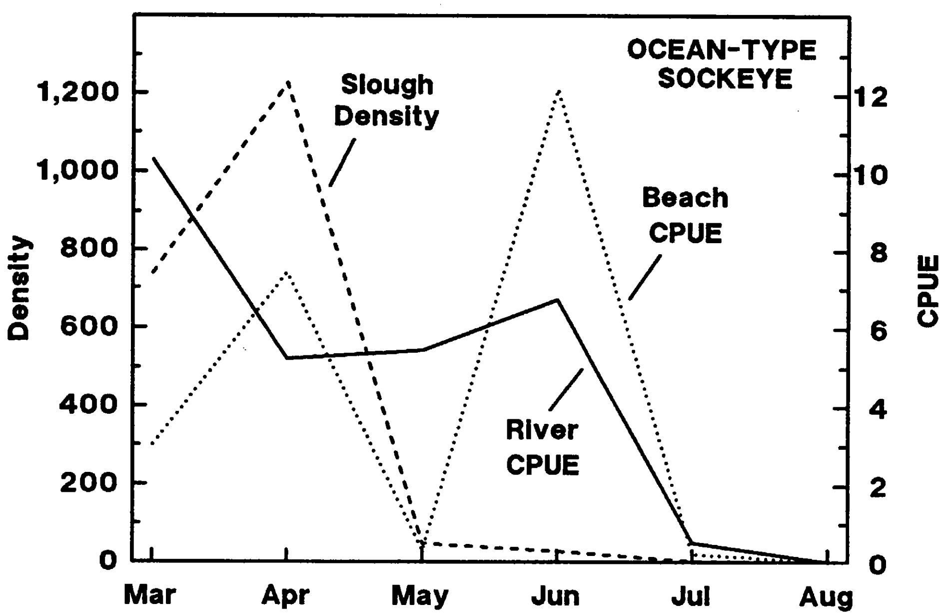

Figure 8.3—Mean density (no./100 m^2) or catch per unit effort (CPUE, no. per seine haul) of ocean-type sockeye from three habitat types in the Situk estuary, March to August 1987 and 1988. Data points are the means of the average density in the two years.

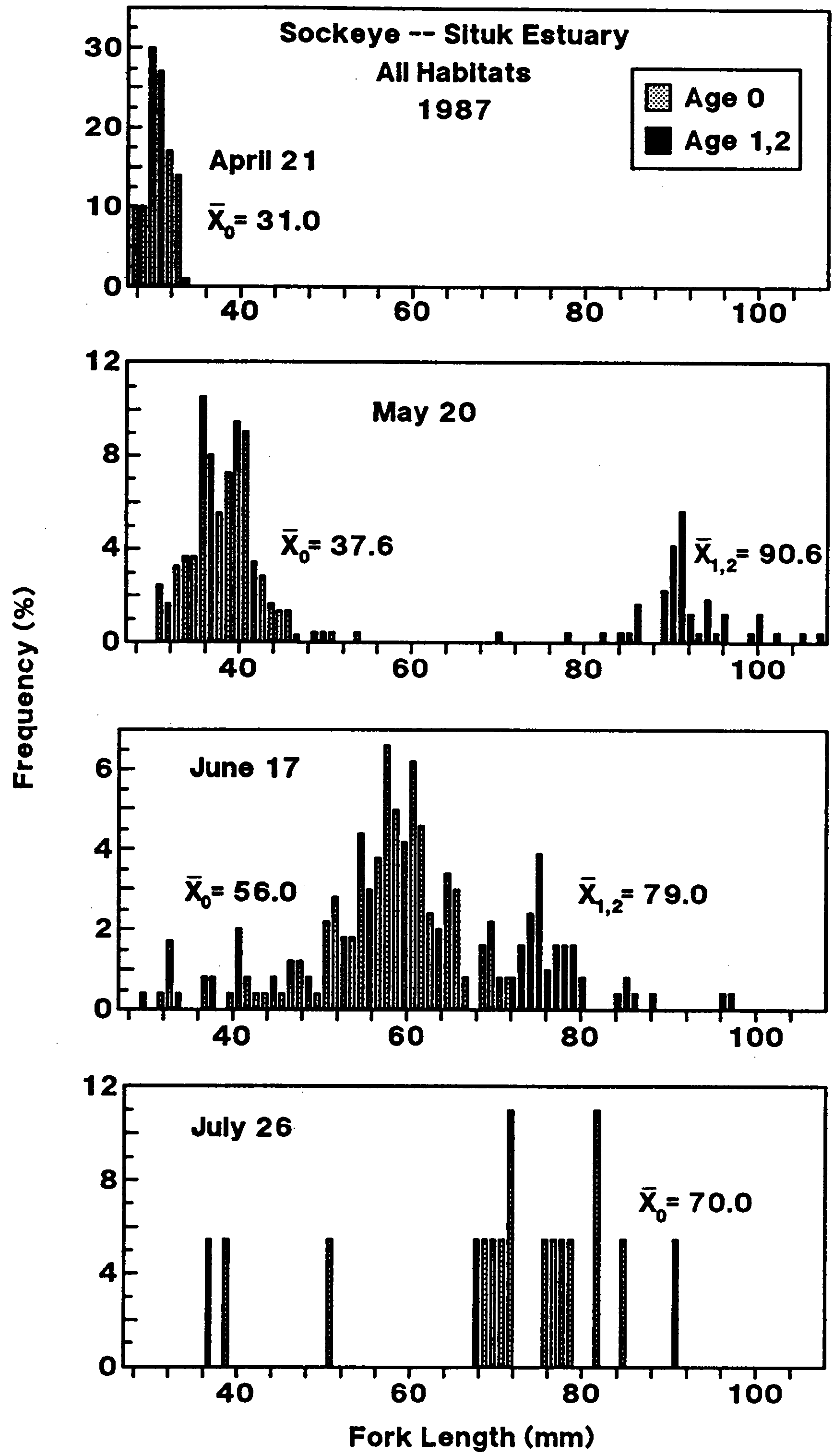

Figure 8.4—Length frequencies of sockeye from the Situk River estuary April to July 1987. Mean FL ($\bar{x}$) is shown for each sampling date and age class (designated by subscript).

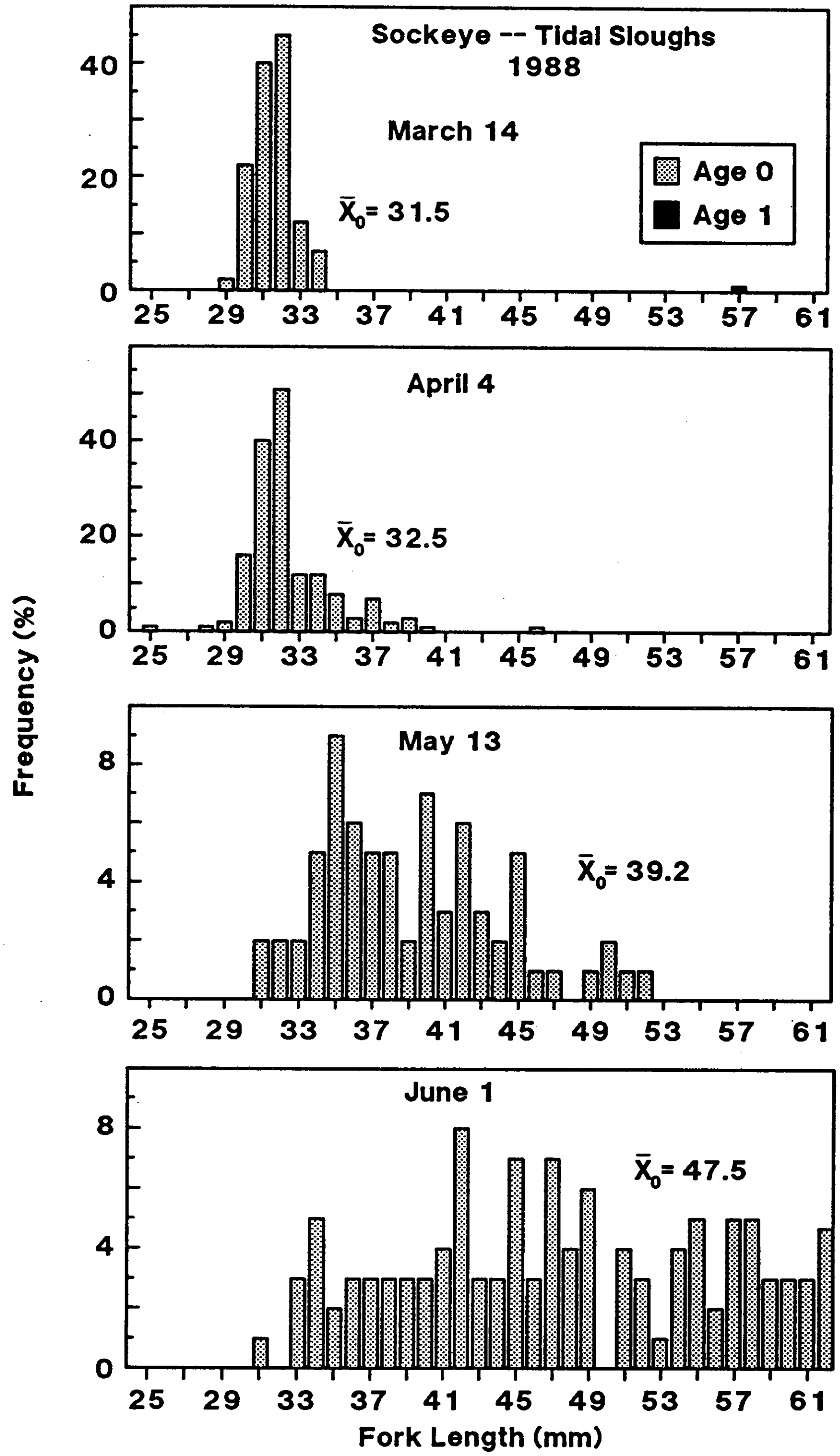

Figure 8.5—Length frequencies of sockeye from tidal sloughs in the Situk estuary March to June 1988. Mean FL ($\bar{x}$) of ocean-type sockeye is shown for each sampling date.

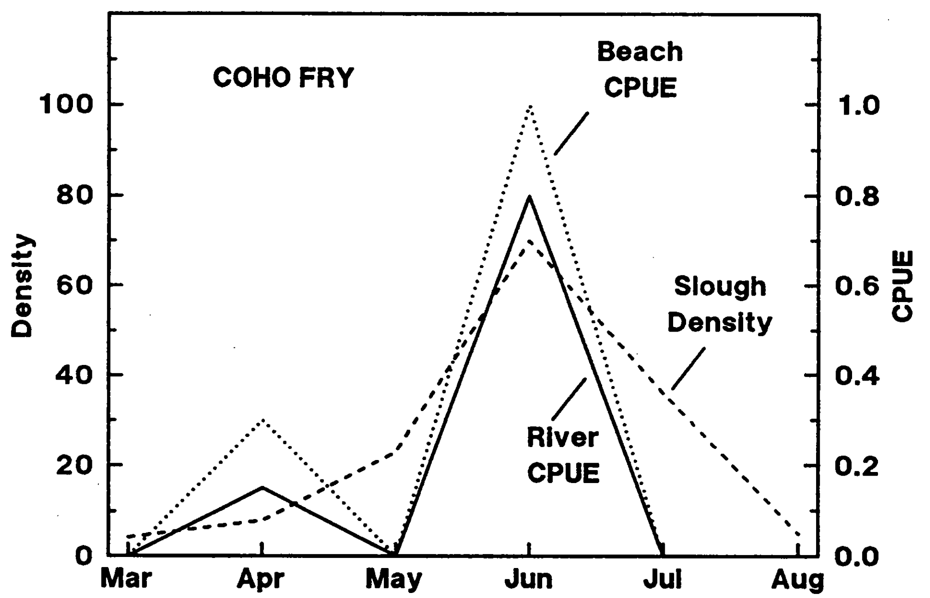

Figure 8.6—Mean density (no./100 m²) or catch per unit effort (CPUE, no. per seine haul) of coho fry from three habitat types in the Situk estuary March to August 1987 and 1988. Data points are the means of the average density in the two years.

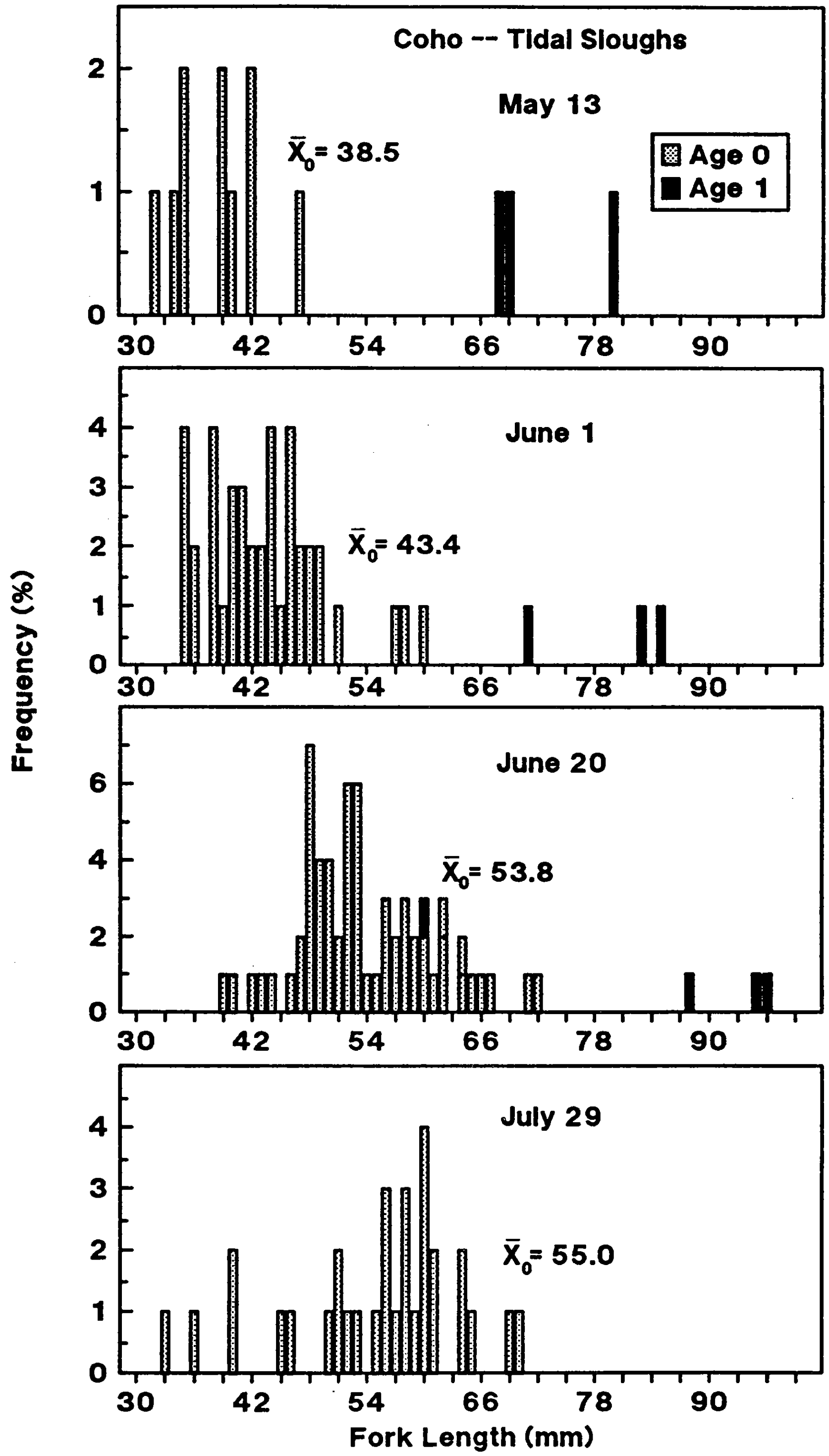

Figure 8.7—Length frequencies of coho from tidal sloughs of the Situk estuary May to July 1988. Mean FL ($\bar{x}$) of coho fry is shown for each sampling date.

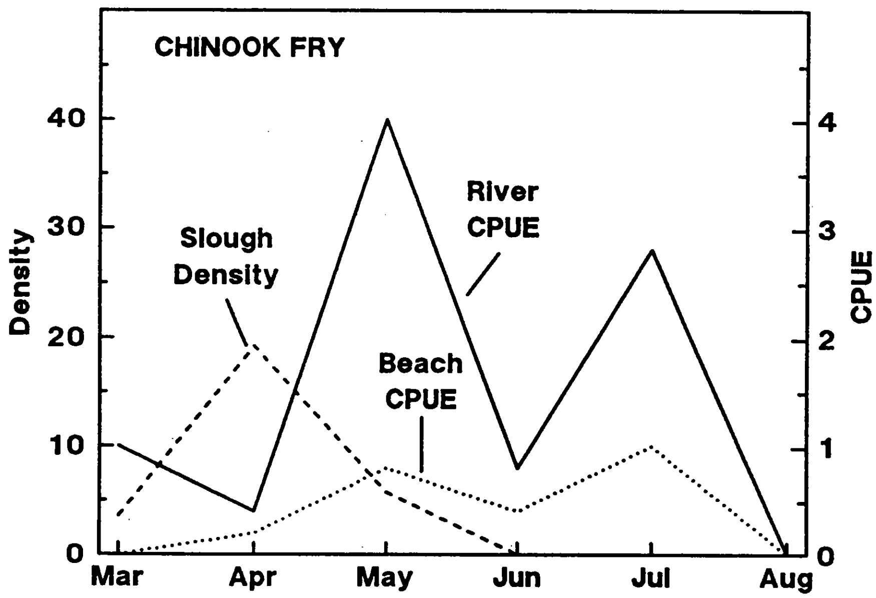

Figure 8.8—Mean density (no./100 m^2) or catch per unit effort (CPUE, no. per seine haul) of chinook fry from three habitat types in the Situk estuary March to August 1988.

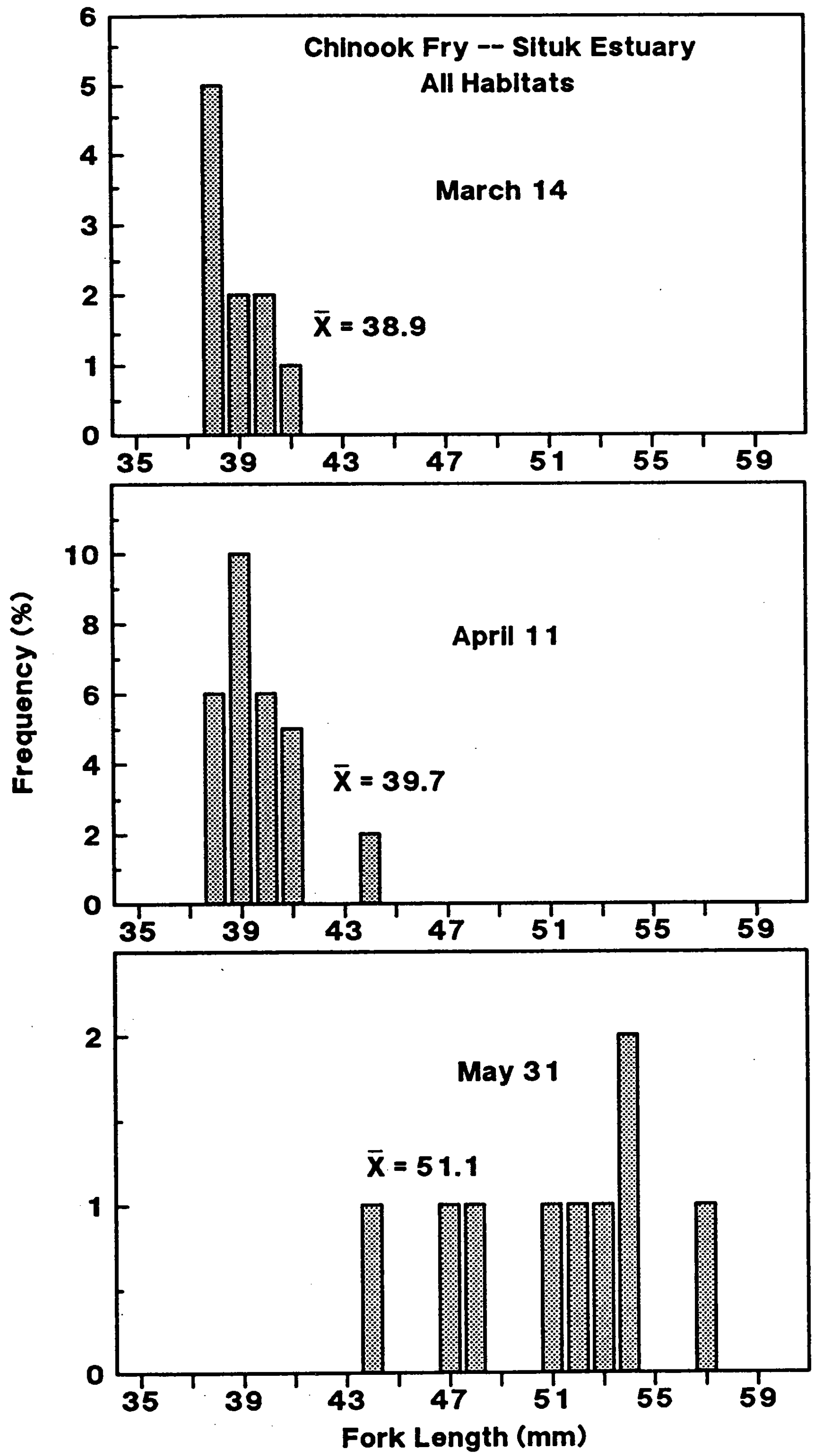

Figure 8.9—Length frequencies of chinook fry from the Situk estuary March to May 1988. Mean FL ($\bar{x}$) is shown for each sampling date.

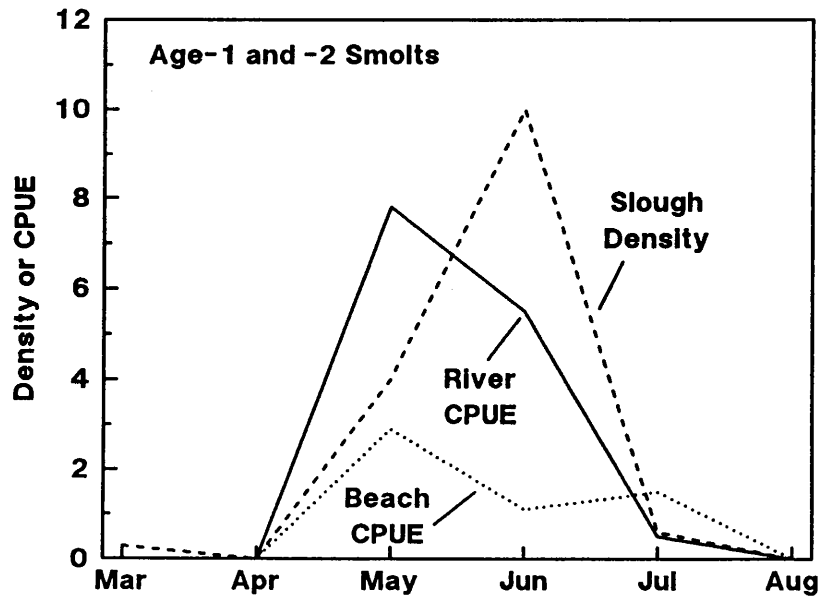

Figure 8.10—Mean density (no./100 m^2) or catch per unit effort (CPUE, no. per seine haul) of age-≥1 salmon smolts from three habitats in the Situk estuary March to August 1987 and 1988. Data are the means of the average density in the two years.

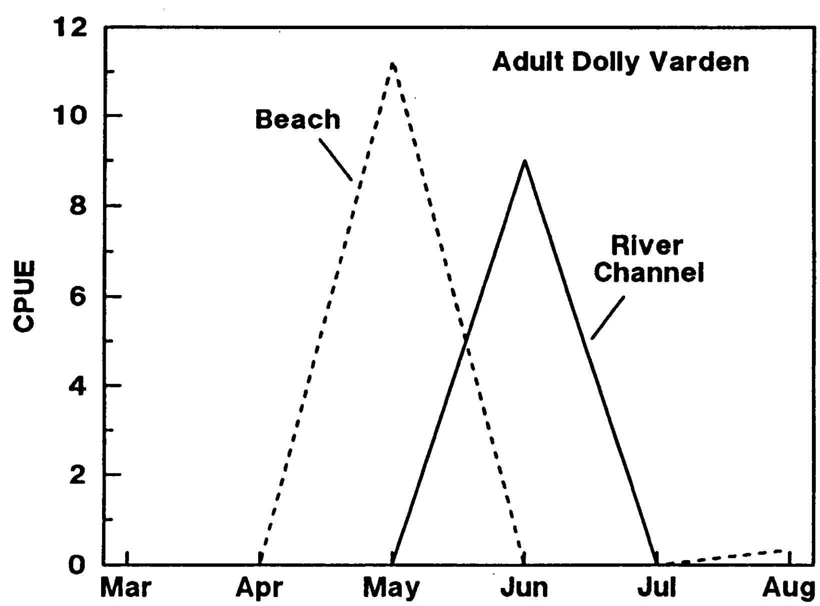

Figure 8.11—Catch per unit effort (CPUE, no. per seine haul) of adult Dolly Varden from river channel and beach habitats in the Situk estuary March to August 1987 and 1988. Data points are the means of the average density in the two years.

STUDY 9.

DISTRIBUTION OF JUVENILE SALMONIDS IN RUSSELL AND NUNATAK FIORD STREAMS

Rationale

After Russell Fiord is dammed by the Hubbard Glacier, rising water in "Russell Lake" will inundate most anadromous fish habitat in all streams entering Russell Fiord and Nunatak Fiord. Knowledge of the distribution of stream-rearing salmonids will enable fisheries managers to estimate losses from flooding and determine appropriate restoration strategies.

Objectives

The objective of this study was to determine the summer distribution of juvenile salmonids in Russell and Nunatak Fiord streams.

Summary of Results

Rearing salmonids were captured in 30 of 102 streams sampled in Russell and Nunatak Fiords in 1988. Juvenile Dolly Varden were widely distributed in the 30 streams, whereas coho were captured in only 9 streams in the southern portion of Russell Fiord. Streams that did not have juvenile salmonids were usually short and steep and had poor spawning and rearing habitat.

METHODS

From 8 July through 15 September 1988, ADF&G personnel surveyed 102 streams in Russell and Nunatak Fiords to document salmonid distribution and species composition. Streams with rearing salmonids were usually sampled more than once (range 2-10 times), whereas streams without rearing salmonids were sampled only once. Two streams cataloged with rearing salmonids in 1988 were resampled in August 1989.

Juvenile fish were captured with baited minnow traps. In 1988, 1-7 traps were placed in the lower 300 m of each stream and fished for 1-2 hours. In 1989, 20 minnow traps were set for 1 hour in a 50 m reach located approximately 200-500 m upstream of each stream's mouth. All juveniles captured were enumerated by species, and any adult fish observed were recorded. Water temperature was measured with a hand-held thermometer, and stream width and depth were visually estimated in every stream. Subjective descriptions of water velocity (slow to very fast) and turbidity (clear to heavily silted) were also recorded.

RESULTS

Thirty streams with rearing salmonids were identified; 20 in the southern quarter of Russell Fiord, 5 in Nunatak Fiord, and 5 in the remainder of Russell Fiord (Fig. 9.1; Table 9.1). Dolly Varden were widely distributed throughout the 30 streams in Russell and Nunatak Fiords, whereas coho salmon were captured only in nine streams in the southern quarter of Russell Fiord (Table 9.1). Catches indicate that Dolly Varden density probably was moderate to high, whereas coho density was low. The only stream where substantial numbers (>100) of juvenile coho were captured was stream number 750 (Fig. 9.1). Between 1988 and 1989, the difference in the observed numbers of coho in stream number 750 and Dolly Varden in stream number 768 (Table 9.1), may have been partially the result of species misidentification. Adult coho (2-100 fish) were observed only in streams 750 and 768 (Fig. 9.1) in September 1988. Other species captured included sculpins and threespine stickleback.

Streams in Russell and Nunatak Fiords that lacked rearing salmonids were typically short and steep, and had poor spawning and rearing habitat. Streams with rearing salmonids were mostly clear, ranging from 1 to 10 m wide, 5 to 60 cm deep, and 5 to 20°C.

DISCUSSION

Dolly Varden were the most common salmonid captured in streams in Russell and Nunatak Fiords; coho were the only other salmonid captured and were scarce. Timing of surveys precluded the capture of other species, such as pink and chum salmon, because they had already emigrated to sea. In addition, no adult pink salmon were observed in any streams in July and August, indicating a possible year-class failure as a result of the 1986 closure of Russell Fiord. The damming of Russell Fiord by Hubbard Glacier from late May to October 1986 may have obstructed the spawning migration of adult pink salmon and resulted in no spawning and consequently no adults in 1988. Historically, pink salmon have been present in Russell Fiord; over 45,000 pinks were harvested by beach seine in 1952 in Yakutat and Disenchantment Bays and Russell Fiord (Knapp 1952).

Most inlet streams in Russell and Nunatak Fiords are "HC" channels (steep, contained streams). According to the USFS Channel Type Classification System, these streams typically provide poor spawning and rearing habitat (Paustian 1992). This agrees with the 1988 fish survey: approximately 70% of the streams examined had no rearing salmonids. Because most fish sampling was conducted in the lower stream reaches, however, some rearing salmonids may have been missed in the upper reaches. In the few streams with rearing salmonids, fish were present in the lower stream reaches where gradient was low; these were often "MM" and "MC" channels (Paustian 1992), which provide low to moderate spawning and rearing habitat (Paustian 1992). (A complete description of channel types in Russell and Nunatak Fiord streams is available from the USFS, S. Paustian, Tongass National Forest, Chatham Area, 204 Siginaka, Sitka, AK 99835).

Table 9.1—Catch of juvenile salmonids in inlet streams in Russell and Nunatak Fiords. Fish were captured in minnow traps from July through September 1988 and August 1989. Streams without salmonids are omitted. Stream locations are shown in Figure 9.1; stream identification numbers, assigned during the 1988 survey, refer to relative distances between streams.

Stream	Coho salmon	Dolly Varden
	Russell Fiord	
1	3	30
9	11	17
15	0	5
42	1	41
52	0	13
73	0	5
75	0	7
90	2	2
100	0	9
251	0	1
606	0	121
610	0	8
644	0	35
652	0	10
655	0	9
677	9	59
689	0	7
707	0	98
719	4	70
730	0	12
736	2	36
750	0 (147)*	89 (50)*
753	0	7
754	0	6
768	2 (31)*	133 (3)*
	Nunatak Fiord	
10	0	4
11	0	4
26	0	2
40	0	3
41	0	3
Total	34 (178)*	846 (53)*

* 1989

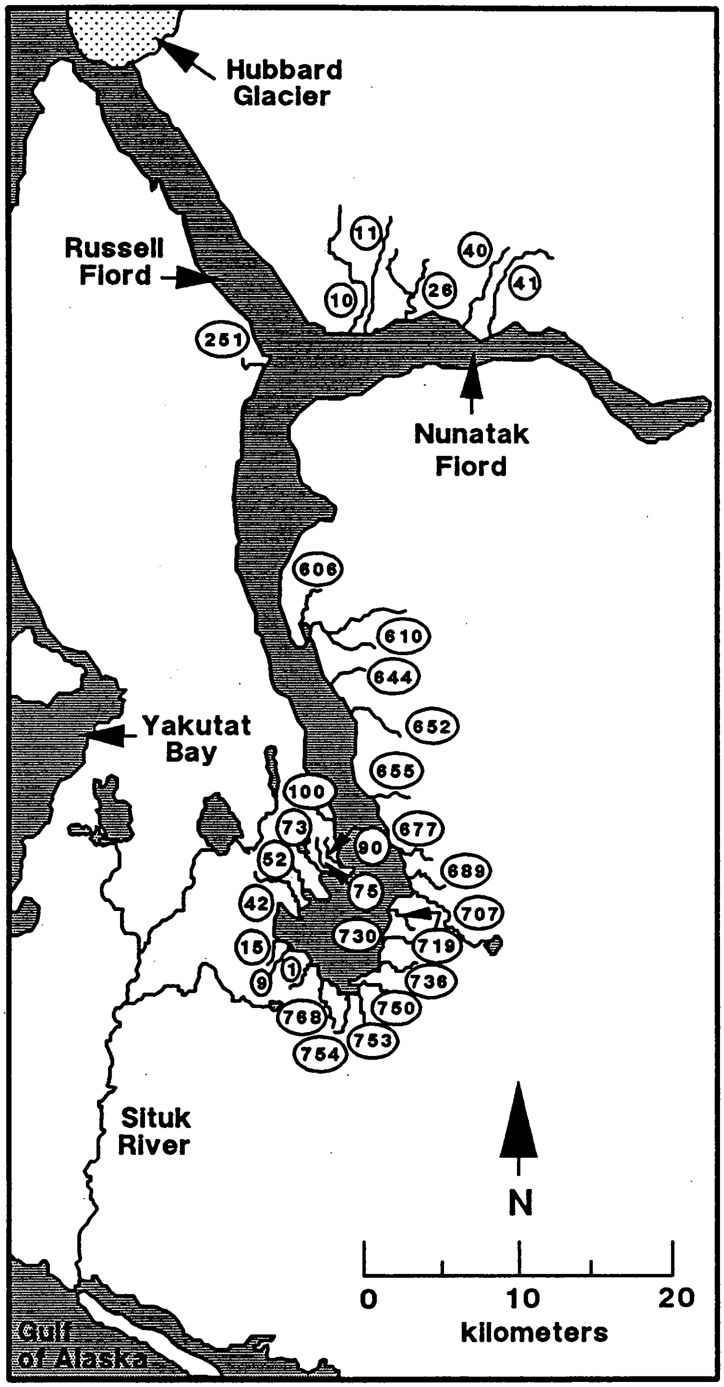

Figure 9.1—Streams with anadromous salmonids in Russell Fiord and Nunatak Fiord, 1988 and 1989. Streams without salmonids are not shown. Stream identification numbers, assigned during the 1988 survey, refer to relative distances between streams.

STUDY 10.

JUVENILE SALMONID ABUNDANCE AND HABITAT AT BASELINE SITES

Rationale

Flooding could drastically alter juvenile salmonid populations and habitat in the Situk and Lost Rivers. Determining juvenile abundance and habitat at specific sites will enable changes to be evaluated after flooding.

Objectives

The objective of this study was to establish base lines for juvenile salmonid abundance and habitat at sites inside and outside the flood zone of the Situk and Lost Rivers so that changes after flooding can be evaluated.

Summary of Results

Juvenile salmonid density was estimated and habitat was measured at two sites outside and three sites inside the flood zone. Sites were sampled once in summer and fall from 1987 through 1990. Coho were captured at all sites and were the most abundant salmonid, whereas sockeye were least abundant and were captured at only two sites. Densities were generally lower in fall than in summer; however, sockeye and Dolly Varden densities were greater in fall at one site and steelhead density was greater at one site in fall. Density varied annually in both summer and fall.

METHODS

Populations of juvenile salmonids were estimated and habitat was characterized at five sites on the Situk and Lost Rivers from 1987 to 1990. Two sites were outside the flood zone (Wad Hole on the main-stem Situk River and Day Glo Creek, a tributary of the Situk River) and three sites were inside the flood zone (Situk Meander, a tributary of Old Situk River; Cable Hole on the main-stem Situk River; and Airport Creek, a tributary of the Lost River) (Fig. 10.1). The sites were the same used in Study 2, and were selected because they had representative fish populations and habitat characteristics, and were reasonably accessible. All sites were sampled in summer and four sites were sampled in fall. Site locations were permanently marked with a global positioning system (Table 10.1). Fish populations were estimated and habitat was measured the same as described in Study 2. Fish densities at the two main-stem Situk River sites were estimated by the removal method and at the other sites by the mark-recapture method. Relative percent difference in density was calculated by the equation:

$$D_i = 100 \frac{\sum_{i=1}^{n-1} (x_i - x_n)}{\sum_{i=1}^{n-1} (x_i + x_n)} , \tag{1}$$

where (D_i) is the relative percent difference in density in site i, x_i is the density in year 1 and x_n is the density in year n. Water temperature was measured with a thermograph at all sites except Cable Hole.

RESULTS

The physical characteristics of the sites differed (Table 10.2, Fig. H.6). Airport Creek was the widest (9.8 m) and the pool habitat at Cable Hole was the deepest (121 cm). The percentage of pool habitat varied from 100% in the pool habitats at Cable Hole and Wad Hole to 37% at Airport Creek. The substrate in Day Glo and Airport Creeks was similar (mean, 44% sand/silt), whereas Situk Meander had nearly twice as much (80% sand/silt). Water velocity and discharge were greatest at Wad Hole and least at Situk Meander. Mean number of LWD pieces varied 14-fold and was greatest in the pools of Wad and Cable Holes, and was absent in willow edges and in Situk Meander. Annual water temperature varied less at Situk Meander than at the other sites because of the influence of ground water at Situk Meander (Fig. H.6).

Not all salmonid species were captured at each site. Coho salmon were at all sites in summer and fall (Table 10.3, Fig. 10.2), but sockeye were captured at only two sites in summer and fall and chinook were found only in summer at the two main-stem sites and in Situk Meander one summer. Steelhead were captured at all sites except Situk Meander in summer and found at all sites in fall. Dolly Varden were captured at all sites in summer and two of four sites in fall.

Seasonal changes in density varied among species and sites (Table 10.3, Fig. 10.2). Coho density decreased at all sites an average of 66% from summer to fall. Sockeye density increased about 1000% in Situk Meander in fall and decreased 95% in Airport Creek in fall. Steelhead density increased over 500% in Day Glo Creek in fall and decreased about 100% in Airport Creek in fall. Dolly Varden density decreased 66% in Day Glo Creek in fall and increased 421% in Situk Meander in fall. In summer and fall, mean annual coho density was highest in 1989 at all sites, but was variable for other species between years (Fig 10.3).

Within each year, density in summer and fall differed among species (Table 10.3). In summer, mean variation among sites was greatest (188%) for chinook and least (95%) for coho (Fig. 10.3). In fall, variation was greatest for steelhead (169%) and least for coho and Dolly Varden (35%). Variation was greater in summer than fall for coho and Dolly Varden, less in summer than fall for sockeye, and similar for steelhead.

Annual variation of fish density differed among sites. For coho in summer, variation of fish density was lowest (8%) at Airport Creek and highest at Cable Hole (pool and willow edge habitats, 151%), whereas in fall, variation ranged from 24% to 53%. For sockeye, annual variation between Airport Creek and Situk Meander was similar in summer (128% and 114%) but different in fall (200% and 115%). Variation of chinook density was similar at the main-stem sites (173%, 190%). Steelhead density variation ranged from 133% to 200% in summer and from 106% to 200% in fall. Variation of Dolly Varden density ranged from 92% to 200% in summer and from 36% to 71% in fall.

DISCUSSION

All study areas are suitable for baseline sites with the possible exception of Day Glo Creek, which is in an area disturbed by logging. Much of Day Glo Creek in the vicinity of and including the baseline site has a buffer zone (about 10-100 m wide) on one or both sides. Logging may affect fish populations and habitat (Murphy et al. 1986; Thedinga et al. 1989) and obscure the potential effects of flooding. All sites had adequate coho populations but the other species were captured only at certain sites. The main-stem sites had all species except sockeye, and the tributary sites each had three or four species depending on season.

Some sites were probably wintering areas for juveniles. Juvenile densities of all species increased from summer to fall in Situk Meander. This site is probably used by juveniles in winter because water temperature is relatively warm due to ground water. The fall increase in steelhead density in Day Glo Creek indicates that some steelhead winter there.

Juvenile densities in fall are less variable than in summer. Density of all species varied considerably between years, seasons, and sites; but based on the annual difference in density, the least variation in density usually occurred in fall. Also, sockeye and steelhead densities were higher in fall than summer in the tributaries. There are disadvantages to sampling in fall however: frequency of freshets increases and most chinook have migrated from the river. Although it would be easier to detect differences in fish abundance in fall, the best time to sample baseline sites is probably late summer before chinook migrate from the river and after fry populations have stabilized. Several more years of data would be useful in determining annual variation in fish abundance.

Table 10.1—Location of benchmark sites and other reference points in the Situk and Lost River watersheds.

Site	Longitude	Latitude
Airport Creek[a]	139°36.45'W	59°28.82'N
Situk boat landing[b]	139°34.36'W	59°26.94'N
Cable Hole[c]	139°34.27'W	59°27.52'N
Wad Hole[c]	139°29.87'W	59°35.23'N
Situk Meander[d]	139°27.59'W	59°34.63'N
Day Glo Creek[c]	139°33.63'W	59°34.68'N
Old Situk River at FH-10[e]	139°26.27'W	59°34.24'N
Nursling Hole[c]	139°33.36'W	59°28.43'N
Mouth of Old Situk River	139°30.43'W	59°33.88'N
Bean Belly Creek at FH-10	139°28.07'W	59°34.83'N
Milk Creek at FH-10	139°35.59'W	59°34.20'N
Situk River at FH-10	139°29.71'W	59°35.17'N

[a]20 m downstream of lower boundary of baseline site.

[b]adjacent to end of road at edge of Situk River.

[c]middle of baseline site.

[d]20 m upstream of lower boundary of baseline site.

[e]Forest Highway 10.

Table 10.2—Physical characteristics of baseline sites on the Situk River and Lost River. Each site was sampled from one to five times. Ranges are in parentheses. A dash indicates characteristic not measured.

Site	Width (m)	Water depth (cm)		Habitat type (%)			Substrate composition (%)			Water velocity cm/s	LWD[*] No./Site	Discharge (m^3/s)
		Mean	Maximum	Pool	Riffle	Glide	Sand/silt	Gravel	Cobble			
Day Glo Creek	2.7 (2.3-2.9)	20 (9-30)	64 (39-110)	49.4 (32.8-63.2)	14.1 (9.8-21.2)	31.6 (15.6-42.6)	43.6 (28.9-58.3)	55.8 (40.4-71.1)	0.6 (0-1.3)	13.8 (4.3-24.9)	11 (4-17)	0.02 (0.01-0.04)
Lost River	9.8 (8.1-11.4)	50 (36-69)	85 (69-110)	37.1 (26.2-46.2)	0	62.9 (53.8-73.8)	45.6	54.4	0	18.7 (10.3-40.2)	2	0.19 (0.03-0.55)
Situk Meander	8.2 (7.7-8.7)	25 (16-29)	48 (42-57)	97.0 (95.8-98.2)	2.0 (1.8-2.1)	1.0 (0-2.1)	80.0	20.0	0	6.8 (2.3-11.2)	0	0.003 (0.002-0.004)
Wad Hole:												
Debris pool	5.1	77	250	100.0	0	0	—	—	—	23.0	14	0.13
Willow edge	4.2	62	90	0	0	100	—	—	—	29.1	0	0.29
Cable Hole:												
Debris pool	7.5	121	260	100.0	0	0	—	—	—	4.4	8	0.14
Willow edge	3.8	75	110	0	0	100	—	—	—	12.5	0	0.07

[*]Large Woody Debris >1 m long and 10 cm diameter.

Table 10.3—Densities (no./100 m²) of juvenile salmonids in summer and fall at baseline sites on the Situk and Lost Rivers, 1987-90.

Site	Date	Coho	Sockeye	Chinook	Steelhead	Dolly Varden
			Summer			
Cable Hole:						
Debris pool	7/26/89	116.7	0	66.3	55.0	67.0
	7/26/90	15.0	0	1.3	7.7	0
Willow edge	7/26/89	179.2	0	166.7	33.8	28.2
	7/26/90	26.3	0	5.0	1.3	0
Day Glo Creek	7/21/87	305.0	0	0	0	1.4
	7/10/89	565.8	0	0	0	6.5
	7/16/90	229.0	0	0	1.7	3.0
Airport Creek	6/15/88	103.0	1.3	0	0.4	0.1
	7/12/89	116.8	0	0	0.8	0
	7/18/90	108.7	2.3	0	0	0.1
Situk Meander	7/28/87	25.3	0	0	0	41.8
	7/11/89	169.2	4.0	0	0	15.4
	7/20/90	62.3	3.0	0.2	0	77.4
Wad Hole:						
Debris pool	7/24/89	2227.0	0	166.5	224.0	10.0
	7/19/90	530.3	0	16.6	34.9	1.3
Willow edge	7/24/89	2334.5	0	196.2	217.7	6.8
	7/19/90	255.1	0	9.1	18.1	1.1
			Fall			
Day Glo Creek	9/19/88	133.6	0	0	16.9	4.6
	9/12/89	169.5	0	0	5.2	2.2
Airport Creek	9/22/88	13.7	0	0	0.1	0
	9/14/89	18.2	0.1	0	0	0
Situk Meander	9/23/88	77.2	38.2	0	0	53.1
	9/13/89	133.2	10.3	0	0.7	76.0
Wad Hole:						
Debris pool	9/21/88	18.2	0	0.2	7.0	0

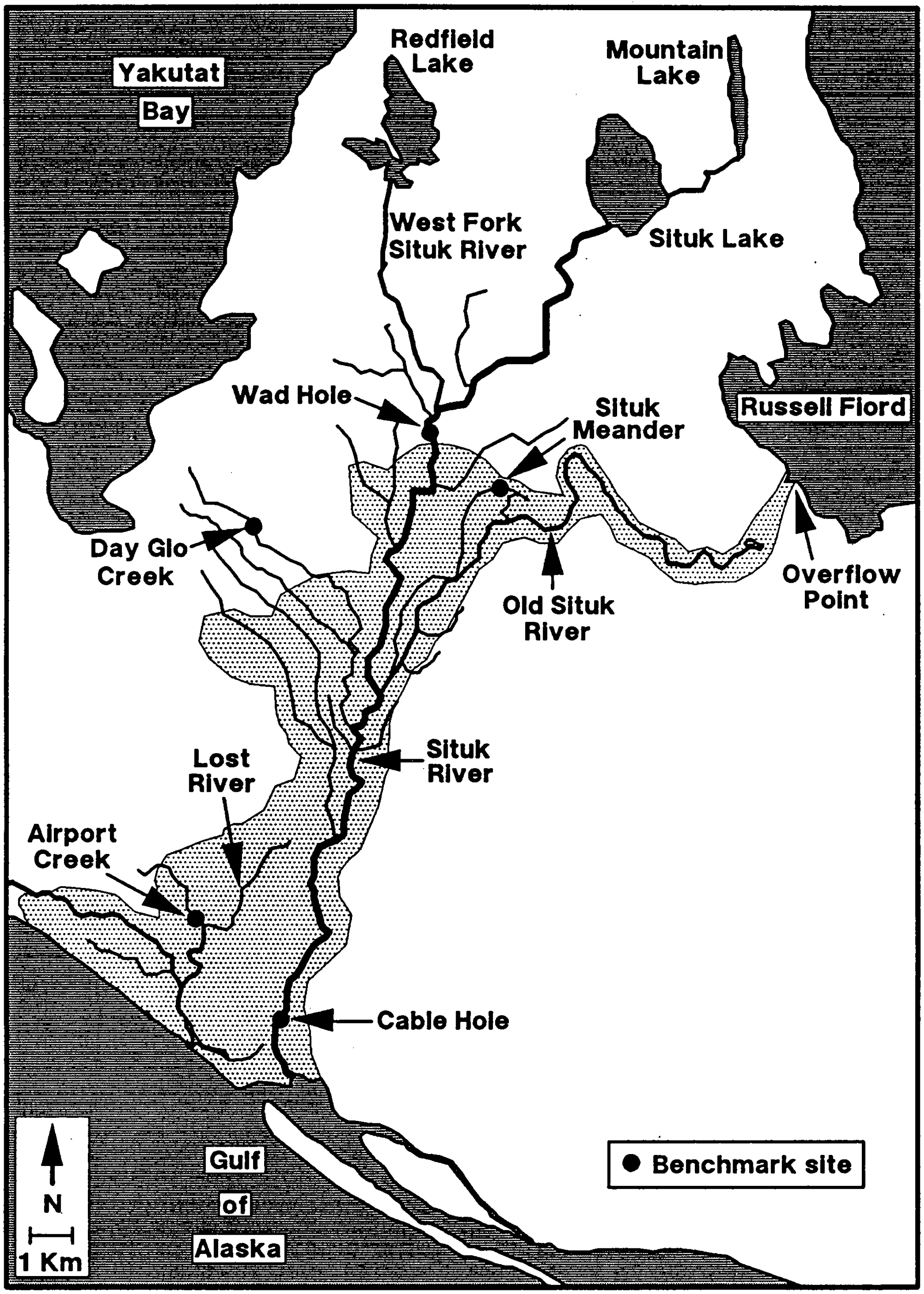

Figure 10.1—Baseline study sites on the Situk River and Lost River, 1987-90.

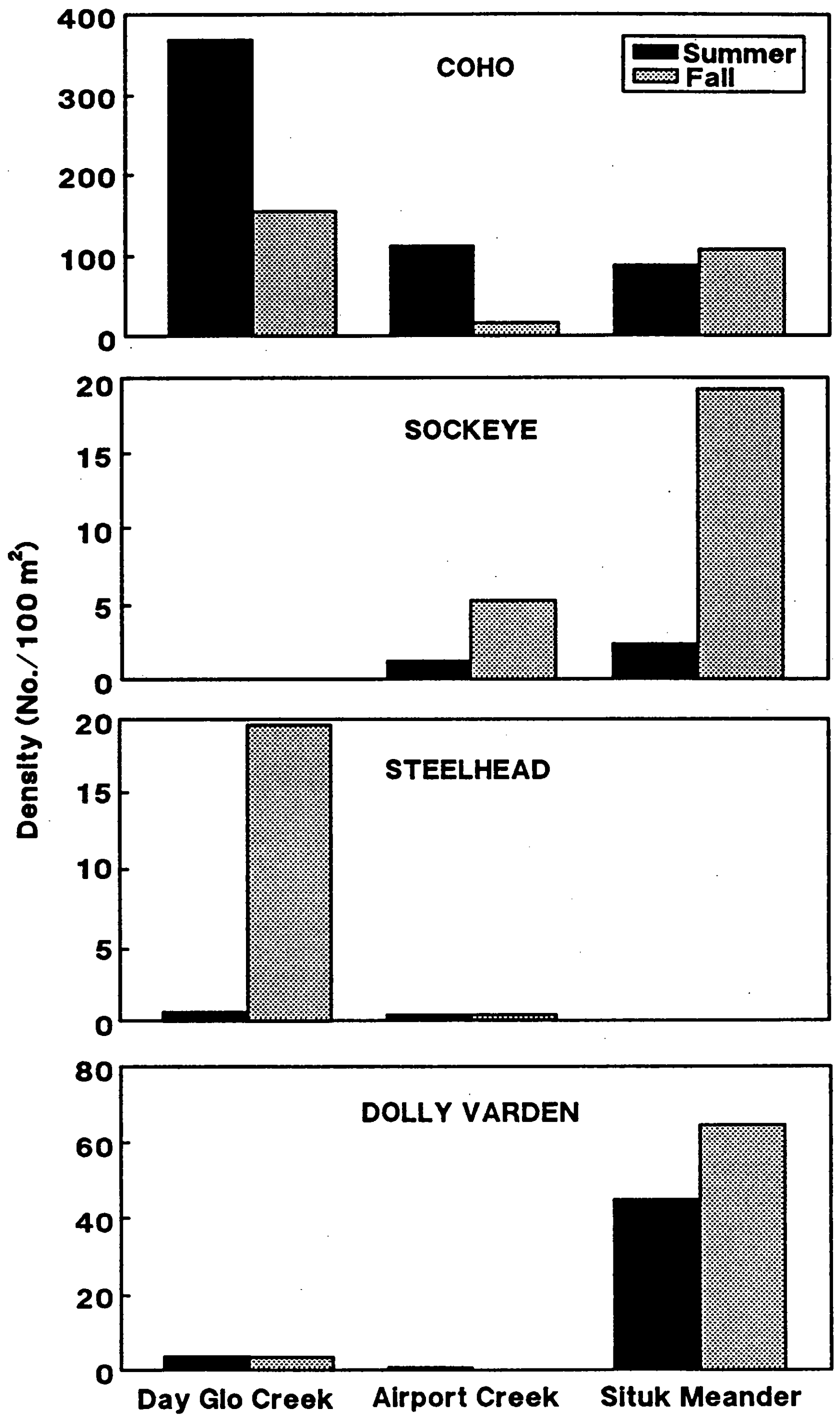

Figure 10.2—Mean seasonal density of juvenile salmonids from baseline sites, Situk River and Lost River, 1987-90. Data are from years and sites when fish density was estimated in both summer and fall.

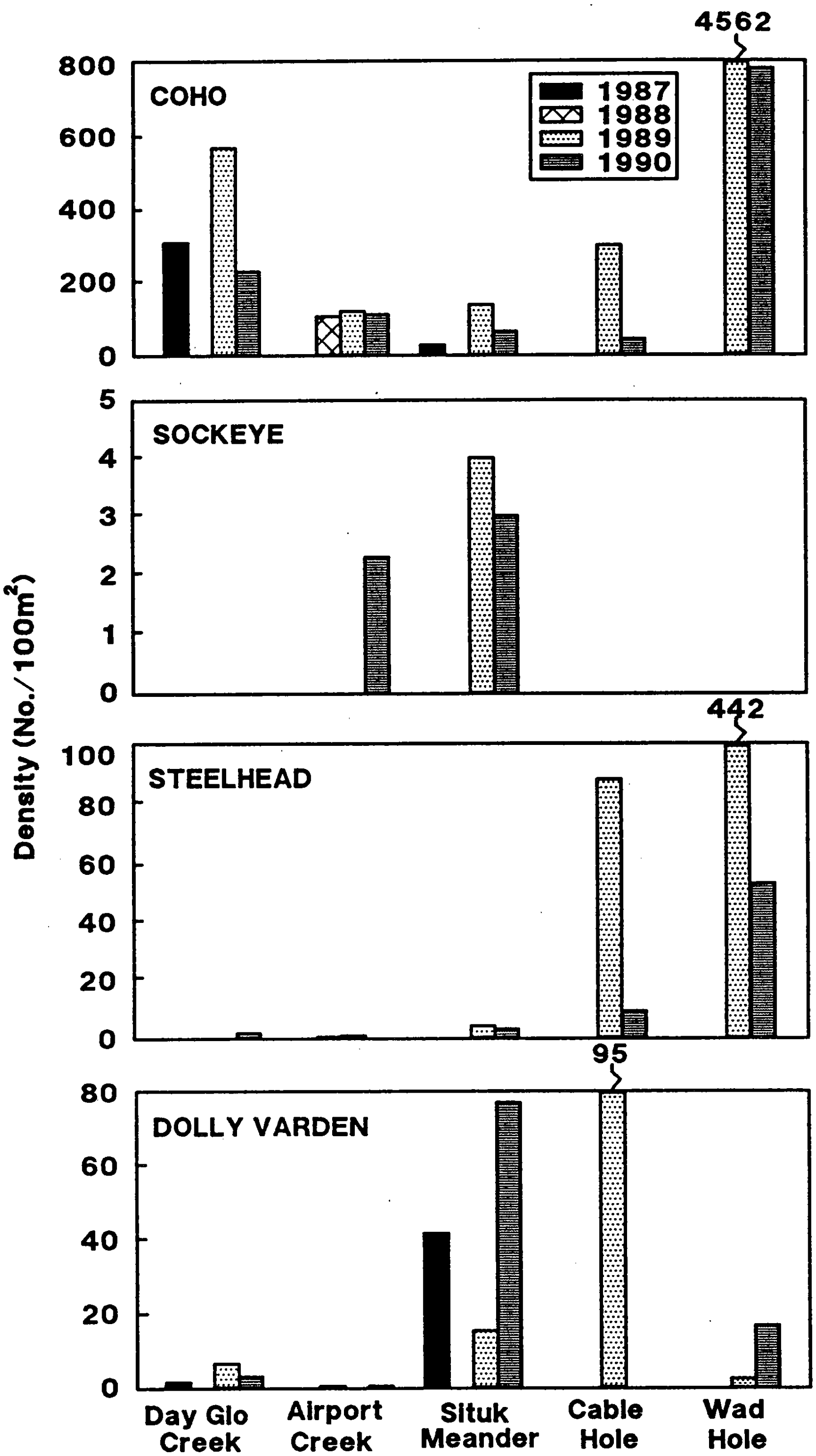

Figure 10.3—Mean annual density of juvenile salmonids from baseline sites in summer, Situk River and Lost River, 1987-90.

EFFECTS ON SITUK RIVER AND RUSSELL FIORD

After Hubbard Glacier impounds Russell Fiord, the newly formed "Russell Lake" would fill in 7-14 months and then overflow into the Situk River. The ice dam will likely form between March and July (Trabant et al. 1991). It may fail and rebuild several times before finally stabilizing, causing extreme oscillations in Situk River flow.

Overflow from Russell Lake would severely impact Old Situk River and the main-stem Situk River downstream from its confluence. Situk River discharge is expected to swell from 6 m^3/s (present summer average) to approximately 220 m^3/s, exceeding 1,400 m^3/s during peak flows (Mayo 1988). The main stem would widen from 25 m (average) up to 2,500 m. Because of glacial runoff into Russell Lake, the "new" Situk River would be cooler and turbid. Old-growth forest in the floodplain would be destroyed, and log jams would intensify flooding. River substrate would be scoured, shifted, and often replaced with sediment. Aquatic vegetation, fish, and invertebrates would be decimated in many areas.

The main stem between Forest Highway 10 and Old Situk River (Fig. H.2) also would be affected as flood waters backed up. This area of the river would be deeper, cooler, and slightly turbid. The river upstream of the highway would not be directly impacted by flooding, but may have increased groundwater flow (Clark and Paustian 1989).

The Situk estuary would be reshaped by flooding. Floodplain analysis indicates that the "new" river would empty directly into the ocean via the Lost River (Paul 1988). The river mouth would be approximately 1,300 m wide, with numerous braids and secondary channels. The mouths of the Ahrnklin and Kunayosh rivers (Figs. H.1, H.2) eventually may move westward and share the Situk River's ocean entrance (Paul 1988). The Situk estuary may increase in size and could contain more tidal sloughs. Temperature and salinity would decrease, and turbidity would increase.

Russell Fiord would change dramatically with the creation of Russell Lake. Rising water would inundate most spawning and rearing habitat in inlet streams, flood 36 km^2 of vegetated shoreline, and increase water surface area from 196 km^2 to 233 km^2 (Clark and Paustian 1989). The lake would develop a surface lens of fresh water and become a sediment trap. Much of the suspended sediment in glacial runoff would settle out in the lake. Water overflowing into the Situk River, therefore, would be less turbid than water entering Russell Lake. A more detailed description of the hydrological effects of flooding on the Situk River and Russell Fiord is provided in Mayo (1988) and Clark and Paustian (1989).

EFFECTS ON SALMONIDS AND HABITAT

The greatest impact on fish habitat would be from initial flooding. Initial effects of flooding on habitat depend on the duration and timing of floods. A single large flood would impact less than a series of floods. After an ice dam in Russell Fiord collapses, Situk River flow would decrease by 90% and many channels would dry up, stranding fish and dewatering redds. Important rearing habitat—such as willow edges and pools with woody debris—would be scoured, filled, or washed away. Spawning habitat would be inundated, covered with debris, or buried in sediment. Rearing fish would be displaced to river margins and off-channel areas or washed to sea. Initially, food production probably would be depressed. Habitats would be unstable for several years as the river channel adjusts to increased flow and changes in sediment and debris.

Eventually, the Situk River would stabilize as it regains its former channel. More rearing habitat could become available because of the creation of Russell Lake and the increased size of the Situk River. Habitat quality, however, would probably be reduced because of cooler water and increased sediment and turbidity.

Adults

Upstream migration of adult anadromous fish would be affected by flooding. During initial flooding, many adult fish may avoid the river because of the extremely high sediment load, as coho and chinook did in the Toutle River, Washington, after Mount St. Helens erupted (Martin et al. 1984). As turbidity decreases with time, fish probably would return, but may change their migration timing and habitat use. For example, pink salmon in the Bella Coola River, British Columbia, delayed migration and used alternate spawning areas to avoid periods of glacial turbidity (Wickett 1958). Adults may migrate sluggishly because of lower water temperature (Bjornn and Reiser 1991), and they may migrate along river margins to avoid high water velocity. The transformation of the Situk River into a large, glacial river does not preclude successful salmonid migration and spawning. Large, glacial rivers in Southeast Alaska (Taku and Stikine Rivers) provide good migration and spawning habitat for adult salmon and steelhead[22] (Eiler et al. 1988).

Effects of flooding on adult fish migration depend on timing and duration of floods. A flood in November, for example, would impact coho and fall steelhead, whereas a flood in June would impact sockeye, chinook, pink, and Dolly Varden (Fig. 1.3). A flood lasting a long time or successive floods over a year would impact all adult salmonids in the Situk River (Fig. 1.3).

Flooding would affect spawning habitat of some species more than others. About 40% of pink and 50% of chum spawn inside the flood zone and would be heavily impacted by flooding. Chinook, sockeye, and fall steelhead would be least affected because most (95%) spawn outside the flood zone. Effects on coho and spring steelhead would be moderate because about 30% of coho and 25% of spring steelhead spawn inside the flood zone. Adult Dolly Varden were not studied, but based on high juvenile densities in Old Situk River (Study 2), most probably spawn inside the flood zone. In addition to salmonids, 100% of eulachon spawn inside the flood zone.

Although the preferred spawning areas of most species would not be directly impacted by flooding, they could be indirectly affected because of competition. Adults that would normally spawn within the flood zone may move to areas away from flooding or may stray to nearby rivers (Elwood and Waters 1969). After Mount St. Helens erupted, coho and chinook straying from the Toutle River increased dramatically (Martin et al. 1984). Redd superimposition and biological oxygen demand from heavier use of unflooded spawning habitat could cause poor freshwater survival (Heard 1978). With returns as high as 300,000 fish, pink salmon would cause the most competition because the majority would probably move from the flood zone to spawn in the upper main-stem Situk River.

During initial flooding, a high percentage of spawning habitat in Old Situk River and the main-stem Situk River would be destroyed by scouring and deposition. Eggs in the gravel would be washed away or buried. If streamflow fluctuates widely, eggs spawned at high water may be dewatered as flow drops. Eggs deposited after the river stabilizes would have longer incubation periods because of cooler water. Late emergence could cause increased freshwater residence, delayed seaward migration, and reduced survival.

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[22]J. Edgington and J. Lynch, Alaska Dep. Fish and Game, Commercial Fish Div., P.0. Box 667, Petersburg, AK 99833. Unpubl. data.

Juveniles

Juvenile salmonids would be affected most if initial flooding is in summer. Overall, about 70% of the juvenile salmonids in the Situk and Lost River watersheds (excluding lakes and most of Tawah Creek watershed) rear in the flood zone in summer. Sockeye would be least affected by flooding because most are lake-type and rear outside the flood zone—nearly all ocean-type sockeye however, rear in the flood zone. Most coho (67%) and Dolly Varden (90%) and about one-half of steelhead rear inside the flood zone in summer. After emergence, chinook fry rear upstream of the flood zone, but nearly all (98%) move downstream and rear inside the flood zone for about 3 weeks while migrating to sea. Thus, flood timing would determine which juvenile fish are initially most affected: a spring flood would spare most chinook; a flood after July would spare most smolts (Fig. P.1). Regardless of timing, juvenile coho, steelhead, and Dolly Varden should recolonize areas disrupted by flooding more quickly than sockeye or chinook because they are more widely distributed in the watershed.

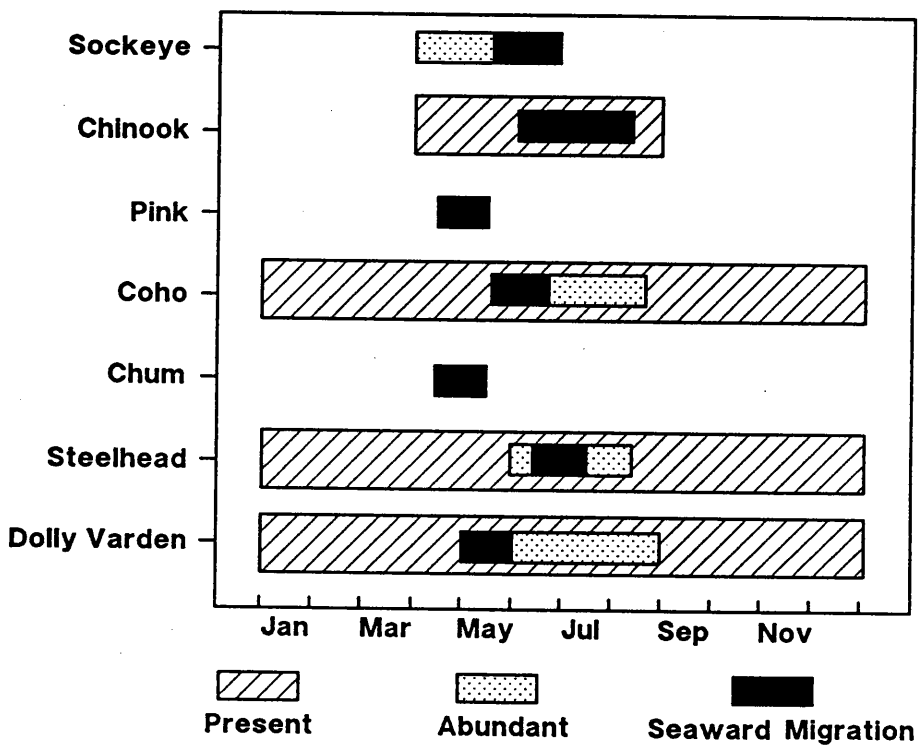

Figure P.1—Estimated time juvenile salmonids are present in the Situk River.

Most juvenile salmonids winter outside the flood zone and would be spared from winter flooding. In fall, juvenile salmonids commonly move to wintering areas (i.e., lakes and tributaries) from which they migrate the next spring as smolts (Cederholm and Scarlett 1981; Murphy et al. 1984; Brown and Hartman 1988). Of the 1.3 million smolts that migrated from the Situk River in 1990 (Study 7), only moderate percentages of sockeye (34%) and coho (33%), and virtually no steelhead wintered inside the flood zone—nearly all chinook migrate to sea their first year and do not winter in fresh water. Thus, most winter habitat would be unaffected by flooding. The Old Situk River, however, is an exception: over 130,000 juvenile salmonids (parr and smolts) emigrated from this tributary in spring 1989 (Study 6). Regardless of where juveniles winter, all seaward migrants must migrate through the flood zone.

The cooler, turbid floodwaters from Russell Lake would affect the distribution, emergence, and growth of some fish species in the Situk River. Studies in the glacial Taku River show that sockeye and chinook rear successfully in turbid waters (<350 NTU), whereas coho and steelhead avoid the turbid river and rear in clearwater tributaries or off-channel beaver ponds (Thedinga et al. 1988; Murphy et al. 1989). Coho, however, successfully rear in the less turbid (<100 NTU) Kenai River, Alaska (Bendock and Bingham 1988).

After flooding, salmonids in the flood zone would emerge later and grow slower. In the lower Taku River, age-0 coho average 50 mm FL in September (Murphy et al. 1989) compared to nearly 70 mm FL in the lower Situk River. Similarly, age-0 chinook in the Taku River average only 60 mm FL by early August (Murphy et al. 1989), whereas by this time in the Situk River they had already migrated to sea at a size of 80 mm FL (Study 4).

Life-history patterns of the ocean-type stocks may disappear after flooding. Most ocean-type sockeye emerge and rear inside the flood zone until they migrate to sea in June. Ocean-type chinook rear within the flood zone for about 3 weeks before migrating to sea. Thus, flooding may eliminate these life-history patterns. Cooler water and slower growth could increase freshwater residence from 4-6 months to 1 or more years, causing increased freshwater mortality. Conversely, ocean-type sockeye may survive and even flourish after the river stabilizes. In the glacial Taku River, ocean-type sockeye rear successfully in side sloughs and beaver ponds (Thedinga et al. 1988).

Estuary

Effects of flooding on anadromous fish habitat in the estuary are uncertain and depend on the configuration of the river channel, basin, barrier islands, and tidal sloughs during initial flooding and after stabilization. The most likely scenario is that the "new" river would develop a delta at its mouth and empty directly into the ocean (Paul 1988). Some ocean-type salmonids that now rear in brackish-water tidal sloughs and the lower river would probably be swept to sea before they could grow large enough to tolerate seawater. Age-1 and older smolts would be less affected because they do not spend much time in the estuary. If the barrier islands and estuary basin remain intact, the estuary could serve as a refuge for age-0 salmonids swept from the "new" Situk River.

Most marine fish species in the estuary, such as starry flounder and sculpin, probably would not be severely impacted by flooding. Marine fish would probably recolonize flood-damaged areas near the river mouth or move to areas adjacent to the Situk River. The loss of the estuary, however, would probably eliminate juvenile Dungeness crabs, which generally prefer estuarine habitats for nursery areas[23].

Russell Fiord

Impoundment would submerge most anadromous fish habitat in Russell Fiord streams. Streams in the fiord are short and steep, and most fish rear and spawn in lower reaches which would be flooded as water rises in the lake. Thus, after impoundment, rearing and spawning would be limited to marginal or unsuitable habitat in fiord streams. Hubbard Glacier would block access to anadromous fish streams in Russell Fiord, but a new migration corridor into Russell Lake would open via the Situk River after the lake is filled. Marine fish and crustaceans entrapped in Russell Lake would eventually die because of anoxic conditions in the deep saltwater lens.

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[23]C. E. O'Clair, National Marine Fisheries Service, Auke Bay Lab., 11305 Glacier Hwy., Juneau, AK 99801-8626. Pers. commun., Aug. 1992.

OVERVIEW

A major goal of restoration in the Situk River watershed after flooding should be to replace or sustain fish stocks and habitat that existed before flooding. Restoration would not have to occur, however, at the same site where fish or habitat was impaired. For example, Canon Beach Creek in the Tawah Creek drainage could be improved to produce more salmon, thus replacing losses in Old Situk River. Restoration strategies are difficult to prioritize because of the magnitude of the potential habitat change from flooding, coupled with the resiliency and adaptability of salmonids. Because of the extensive habitat loss predicted from flooding, large-scale restoration efforts should be directed toward specific stocks or habitats at risk.

The restoration strategies we have identified for replacing fish and habitat in the Situk River assume total loss of all fish inside the flood zone. Undoubtedly, not all juveniles or adults will be lost; some will be displaced to other areas of the river and would still contribute to total production. Because the Situk River will be larger after flooding, more rearing habitat would be available on river margins and secondary flood plain channels. In addition, the creation of Russell Lake would potentially provide a major new rearing and wintering area for juveniles. Thus, creation of new habitat after flooding will partially restore some losses from flooding.

Several "enhancement" projects have been attempted in the Yakutat area since the early 1970s and may serve as guides for restoration. The effectiveness of these projects, however, was never fully evaluated. These projects were reviewed in the Yakutat Comprehensive Salmon Plan (ADF&G 1984) and included conversion of gravel pits to rearing ponds, relocation of stranded fish, enhancement of spawning areas, and woody debris manipulation. Mattson (1976) surveyed potential salmon enhancement sites (e.g., hatcheries) near Yakutat for the Yak-Tat Kwaan Corporation—Roosevelt Creek near Knight Island was the only possible site with sufficient water for a conventional salmon hatchery.

The greatest potential for restoration in the Yakutat area is the development of groundwater sources for spawning channels, rearing ponds, and egg-incubation facilities (e.g., egg boxes). Groundwater channels are inexpensive to construct, can be built with minimal disturbance, and are productive. Successful groundwater spawning channels have been developed in Southeast Alaska near Haines (Bachen 1984) and Hyder (Rickel 1984) for chum and coho salmon. In British Columbia, spawning channels 300-1,000 m long and 5-6 m wide have produced escapements of nearly 250 coho within 3 years; in subsequent years, escapements increased 2- to 8-fold (Sheng et al. 1990). These same channels also provide important winter habitat for coho and have produced 300 coho smolts/100 m^2. In Alaska's Gulkana River, groundwater-fed incubation boxes have been successful in enhancing sockeye production (Roberson and Holder 1987). Areas in the Situk River and neighboring watersheds with sufficient groundwater for spawning and rearing channels (or ponds) include Cannon Beach Creek, Milk Creek, ponds on Tawah Creek drainage near Yakutat airport, and Bean Belly Creek and Greens Pond in the upper watershed between Situk River and Old Situk River (Table R.1; Fig. R.1). Four gravel-pit rearing ponds near Yakutat are currently utilized by juvenile coho (Bryant 1988).

Several criteria were used to rank Situk River salmonids in order of potential risk to damage from flooding and need for restoration. These criteria included their current status (run strength), life stage(s) of the stocks affected, amount of critical habitat lost, uniqueness of the stock, importance to fisheries (i.e., subsistence, recreational, commercial), and feasibility of restoration. Species in order of highest risk are steelhead (spring and fall stocks), chinook (ocean type), sockeye (ocean type), and coho (Table R.2). Fish losses and possible restoration strategies for each species are discussed below. Other species would also be affected by flooding, but restoration should be lower priority because they are of little commercial importance, and either their run size is small (chum salmon) or they are widely distributed throughout the Situk River watershed (pink salmon, Dolly Varden).

Table R.1—Summary of possible restoration strategies for adult and juvenile salmonids in the Situk River and neighboring watersheds. Specific restoration sites are shown in Figure R.1.

Restoration activity and site	Stock*
Egg incubation facility:	
Ophir Creek	sockeye, coho, chinook
Milk Creek	chinook
Cannon Beach Creek	chinook, sockeye
Bean Belly Creek	chinook
Egg incubation boxes:	
Russell Lake	sockeye, coho
Outside flood zone	steelhead
Fry stocking:	
Russell Lake	sockeye, coho
Tawah Creek	sockeye, coho
Spawning/Rearing channels:	
Cannon Beach Creek	sockeye, coho
Milk Creek	chinook, steelhead, coho, sockeye
Tawah Creek	sockeye, coho
Bean Belly Creek	steelhead, chinook, coho, sockeye
Rearing Ponds:	
Greens Pond	sockeye, coho
Airport Ponds	sockeye, coho
Lake fertilization:	
Situk Lake	sockeye
Mountain Lake	sockeye
Redfield Lake	sockeye
Enhancement/Restoration:	
West Fork Situk River	steelhead

* Sockeye and chinook are ocean type, steelhead are spring run.

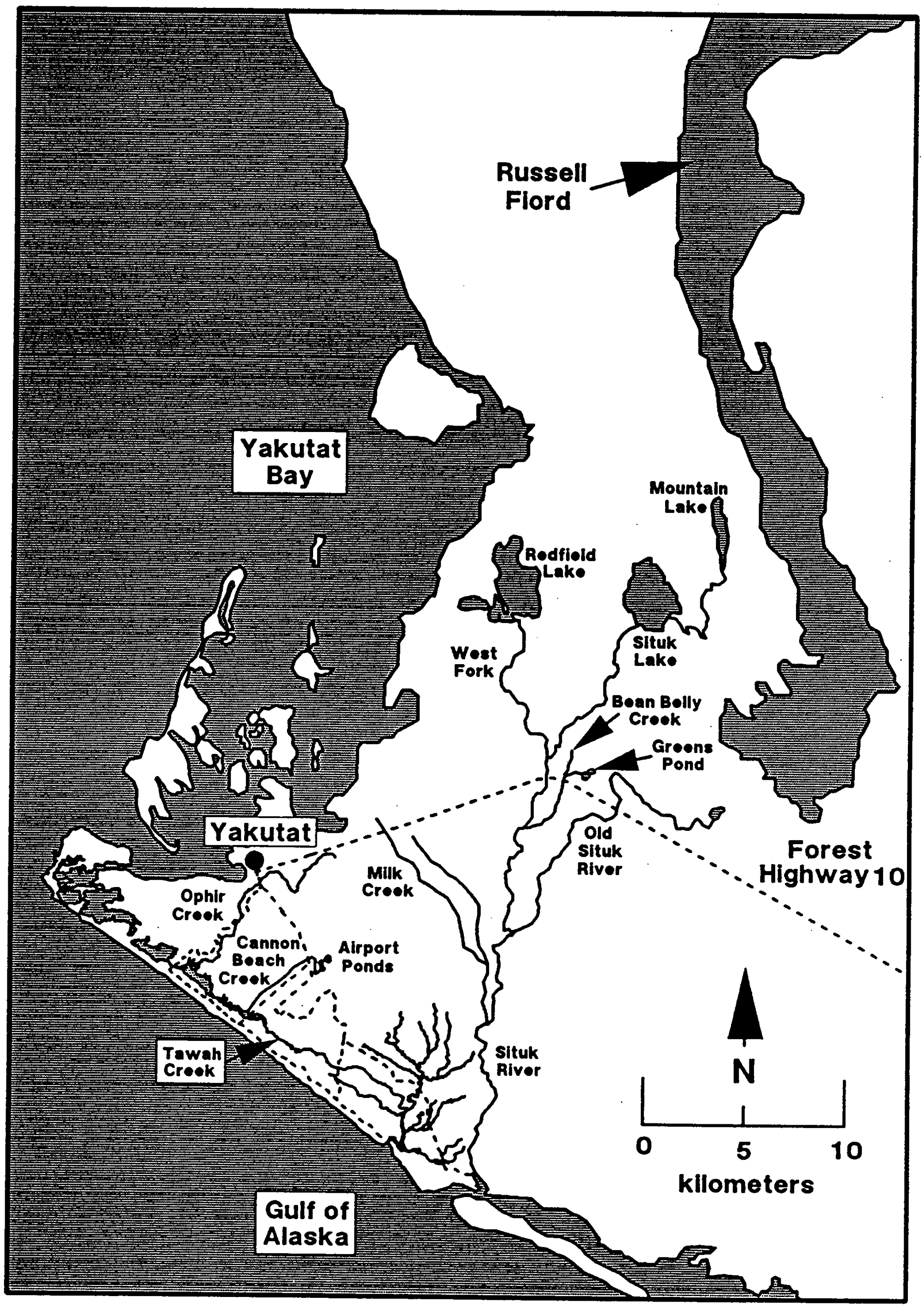

Figure R.1—Location of possible restoration sites in the Situk River and adjacent watersheds.

SPECIES RESTORATION STRATEGIES

Steelhead Trout (Spring and Fall Stocks)

Steelhead are at highest risk to potential impacts from flooding because of their uniqueness (i.e., spring and fall stocks), high value as a sport fish, the amount of critical spawning and rearing habitat affected, and the current depressed status of both stocks. In 1991 and 1992, the Situk River was closed to the taking of steelhead, and only "catch and release" angling was allowed. The estimated total run of both stocks is currently only about 3,000 fish.[24]

Adult spring steelhead are more at risk from flooding than fall steelhead, whereas juveniles of both stocks will probably be equally impacted. Spawning habitat for about 1,000 spring steelhead (2,000 m^2) is inside the flood zone (Study 1) and may need to be replaced by restoration (Table R.2); most fall steelhead spawn in the upper river outside the flood zone. About 50% (62,000) of all juvenile steelhead rear within the flood zone (Table R.2). Based on the average of the highest three rearing densities observed in the Situk River (Study 2), about 62,000 m^2 of rearing habitat would be needed to offset the potential total loss of juvenile steelhead in the flood zone (Table R.2).

The best restoration option for steelhead may be to rebuild the run size prior to flooding. At present, prohibiting log jam and woody debris removal in the stream for boat navigation would help protect spawning and rearing habitat. Requiring only artificial lures and continuing "catch and release" regulations on steelhead should help rebuild the run. Incidental catch of "dropout" or spent steelhead in the set-net fishery should be monitored to determine its effect on repeat spawners. After flooding, construction of groundwater channels in Milk Creek and Bean Belly Creek (Fig. R.1) could provide limited spawning and rearing habitat for steelhead.

[24]Mike Bethers, Alaska Dep. Fish and Game, Div. Sport Fish, Southeast Region, 802 Third St., Douglas, AK 99824. Pers. commun., Feb. 1992.

Table R.2—Salmonid habitat requirements, predicted maximum loss in flood zone, and restoration needs in the Situk River, Alaska.

	Habitat requirements			Predicted maximum loss				Restoration
		Rearing						
Species	Spawning[a] (m^2/♀)	Average[b] (m^2/fish)	Optimum[c] (m^2/fish)	No. Adults[d]	Spawning[e] habitat (m^2)	No. Juveniles[f]	Rearing[g] habitat (m^2)	Juvenile habitat[h] (m^2)
Steelhead	4	3.7	1.0	1,000[i]	2,000	62,000[j]	229,000	62,000
Chinook	20	4.2	1.2	100	1,000	67,000	281,000	80,000
Sockeye[k]	4	9.1	1.2	5,000	10,000	85,000	774,000	102,000
Coho	4	0.3	0.1	10,000	20,000	2,800,000	840,000	280,000
Pink	1	NA	NA	60,000	30,000	NA	NA	NA
Chum	2	NA	NA	200	200	NA	NA	NA
Dolly Varden	0.5	2.2	0.3	3,000	750	586,000	1,289,000	176,000

[a]Based on ♀ redd requirements from Study 1.
[b]Habitat requirements = area/average rearing density weighted by channel type from Study 2.
[c]Habitat requirements = area/mean of 3 highest rearing densities from Study 2.
[d]Predicted loss from Study 1.
[e]Assume sex ratio of 50:50 and specific redd requirement for ♀.
[f]Predicted loss from Study 2.
[g]Predicted loss based on average rearing density from Study 2.
[h]Habitat restoration needs based on optimum density expected from restoration activity; adult habitat restoration needs = predicted loss.
[i]Spring stock.
[j]Spring and fall stocks.
[k]Ocean type.

Chinook Salmon

Chinook salmon in the Situk River are ranked at high risk because of their uniqueness (only the second documented ocean-type stock in Alaska), importance to Yakutat fisheries, and potential habitat loss. The ocean-type life history may disappear because of decreases in water temperature and food abundance; fish may rear in the river a year or more before migrating to sea instead of the present 4-6 months.

Adult chinook may be less impacted from flooding than juveniles. Most adults spawn in the upper river outside the flood zone. About 100 chinook, however, spawn in the flood zone and if none could spawn there after flooding, about 1,000 m^2 of new spawning habitat would need to be replaced (Study 1; Table R.2). About 67,000 juvenile chinook rear inside the flood zone; therefore, about 80,000 m^2 of new rearing habitat would be needed to offset a total loss of this habitat (Table R.2).

To restore some of the lost spawning and rearing habitat for chinook, groundwater channels in Milk and Bean Belly Creeks could be developed. To supplement natural production, egg-incubation facilities could be constructed in Milk, Bean Belly, Cannon Beach, or Ophir Creeks, and chinook fry could be released into the upper Situk River until the river stabilizes.

Sockeye Salmon (Ocean Type)

Ocean-type sockeye, which predominately use Old Situk River, would be the sockeye stock most severely impacted by flooding. This stock was ranked at high risk because of its uncommon life history and because both its spawning and rearing habitats in Old Situk River are located in the flood zone and will be severely impacted.

About 5,000 sockeye spawners, predominately ocean type, would be impacted by flooding; approximately 10,000 m^2 of new spawning habitat would be required to maintain the spawning population (Study 1; Table R.2). Construction of groundwater channels at Milk or Bean Belly Creeks, or in some other tributary in the upper Situk River could replace some of the lost spawning and rearing habitat. New rearing habitat for about 85,000 juvenile sockeye (102,000 m^2) would be necessary to replace that impacted by flooding (Table R.2). To sustain the ocean-type life history, such habitat must contain relatively stable water temperature and abundant food.

Off-site restoration or enhancement could be developed to utilize the extensive rearing habitat in the Tawah Creek drainage (Fig. R.1). Egg-incubation facilities in Cannon Beach or Ophir Creeks could supply sockeye fry for introduction into off-channel areas of Old Situk River or Tawah Creek, or for rearing in saltwater pens, as is being done by Southeast Regional Aquaculture Association in Ketchikan and NMFS[25] in Auke Bay, Alaska. The ocean-type life history could provide an excellent opportunity for a private non-profit hatchery venture in the Yakutat area. A hatchery could also provide fry for stocking the upper Situk River and Russell Lake.

Coho Salmon

In terms of numbers of fish displaced or amount of habitat lost, coho would suffer the greatest overall impact from flooding. Coho were not ranked as high a risk as other species, however, because they are abundant, widely distributed throughout the watershed, and do not exhibit any known unique life history. Initially, coho production will probably decrease because the amount and quality of habitat will be reduced in the flood zone. Flooding would impact most coho life stages and their habitats except winter habitat in lakes and sloughs. Coho, however, were considered the most feasible species for habitat restoration and they would probably benefit from efforts to restore other species.

[25]Jerry Taylor, National Marine Fisheries Service, Auke Bay Fisheries Lab., 11305 Glacier Hwy., Juneau, AK 99801. Pers. commun.

Both adult and juvenile coho would be affected by flooding. Approximately 10,000 adult coho spawn in the flood zone; thus, after flooding, to replace a total loss of spawning habitat, about 20,000 m^2 of spawning habitat would need to be developed. (Study 1; Table R.2). Nearly 3 million juvenile coho rear in the flood zone in summer. To replace a total loss of coho rearing habitat after flooding, about 280,000 m^2 of habitat (Table R.2) would be needed. Obviously, it would not be feasible to create enough new habitat to totally compensate for the potential habitat loss.

Development of groundwater channels would help restore some of the lost coho habitat. Construction of channels in Milk and Bean Belly Creeks could provide about 20,000 m^2 of spawning and rearing habitat. Development of groundwater in Cannon Beach Creek, which is already utilized by coho, could provide about 15,000 m^2 of spawning and rearing habitat. Improvement of the existing 14 man-made ponds in the Yakutat area (ADF&G 1984) and construction of new rearing ponds could provide additional rearing habitat.

OTHER RESTORATION STRATEGIES

Habitat enhancement of other river systems in the Yakutat forelands (e.g., Ahrnklin, Italio, Akwe, Dome, and East Rivers) could provide increased harvest levels to assist fishermen displaced from the Situk River. ADF&G's program to evaluate lake productivity in the Situk River watershed (i.e., Redfield, Mountain, and Situk Lakes) should be actively pursued. If fertilization would be beneficial, salmonid stocks could be enhanced prior to flooding to ensure that runs are at a high level of abundance and able to withstand flooding impacts. The "new" Russell Lake may support rearing sockeye.

Fishery management could also be used to reduce some of the impacts of flooding on fisheries. Management of pink salmon escapement may be necessary to alleviate competition with other species on the spawning grounds and prevent redd superimposition. Perhaps, a special seine or gill-net fishery could be implemented to harvest pinks before they enter the Situk River.

A floodwater-diversion structure and floodplain clearing are possible restoration projects suggested by other agencies. Construction of a dam in the headwaters of Old Situk River and a canal to divert flood waters away from the main-stem Situk River is not warranted because of cost ($48 million) and unknown impacts to other areas of the Yakutat Forelands (Paul 1988; Clark and Paustian 1989). Removal of trees and brush from inside the flood zone could speed the development of a stable channel and control the path of flood waters. This would be detrimental to salmonids, however, because riparian vegetation and instream woody debris are important components of their habitat (Murphy et al. 1987). Removal of riparian vegetation would reduce cover, food supply, streambank stability, and pool formation for many years and, thus, should not be done.

In summary, resource managers would have some lead time to implement appropriate restoration strategies because Russell Lake would take up to 14 months to fill. Timing and duration of flooding would determine what species or stocks warrant restoration. Restoration efforts should concentrate on species or stocks with high commercial or sport value (sockeye, coho, steelhead) or those with uncommon life histories (ocean-type sockeye and chinook). Possible restoration strategies include groundwater spawning and rearing channels, fry stocking, and off-site egg-incubation facilities. Egg-incubation facilities and fry planting must rely solely on Situk River and Lost River stocks instead of other stocks to prevent the introduction of disease and maintain genetic integrity. Costly restoration efforts should be limited within the initial years of flooding to evaluate how fish populations and habitat recover naturally.

FUTURE RESEARCH

Before flooding, pilot studies should be done to evaluate the effectiveness of the identified restoration strategies. One of the suggested groundwater sites (e.g., Milk Creek) could be developed before flooding to evaluate the potential capacity to replace damaged habitat. Therefore, the proper area and design of spawning and rearing channels needed for restoration would be known. Groundwater sources should be evaluated to determine areas in the Situk River watershed where flow is sufficient to provide year-round water to spawning and rearing channels. Carrying capacity should be determined for Tawah Creek, Ophir Creek, upper Situk River, Redfield Lake, and West Fork to identify areas that could accommodate more spawning and rearing fish. To better predict the effects of increased adult salmon spawning outside the flood zone, the effects of stock interaction should be studied. Smolt yield should be determined again to establish a baseline for smolt yield and to quantify smolt predation and identify its source. The contribution of rearing ponds to smolt production should be evaluated before any ponds are enhanced or new ones created. Although restoration in Russell Lake will be difficult because of its wilderness classification, Russell Lake should be studied after flooding for the feasibility of rearing sockeye. Fish populations and habitat should be monitored at established baseline sites (Study 10) for several years before and after flooding to evaluate restoration effectiveness.

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APPENDICES

Appendix 1.—Characteristics of anadromous fish spawning habitat.

Part 1.—Means (standard deviations in parentheses) for some spawning habitat characteristics of sockeye and chinook salmon in the Situk River, 1988.

	Redd dimensions			Water		Substrate composition			Temperature (°C)	
	Length (m)	Width (m)	Area (m^2)	Depth (cm)	Velocity (cm/s)	Fine (%)	Gravel (%)	Coarse (%)	Water column	Intra-gravel
Sockeye	2.4 (0.7)	1.6 (0.4)	3.7 (2.2)	49.6 (17.3)	26.6 (33.0)	23.4 (14.4)	72.0 (17.9)	5.0 (12.8)	9.1 (2.2)	6.2 (2.0)
Chinook	5.6 (1.0)	3.3 (0.8)	19.0 (6.7)	79.6 (23.3)	73.0 (22.4)	5.3 (6.0)	76.1 (18.3)	18.7 (18.1)	12.2 (0.7)	11.9 (0.6)

Part 2.—Characteristics of spawning habitat commonly used by salmonids that spawn in the Situk River. A dash indicates that data were unavailable.

	Spawning site[a]		Water[a]		Substrate composition[b]			Temperature[a]	
	Redd area (m^2)	Area occupied (m^2)	Depth (cm)	Velocity (cm/s)	Fine (%)	Gravel (%)	Coarse (%)	Spawning (°C)	Incubation (°C)
Sockeye	1.8	6.7	>15	21-101	7.5	92	0.5	10.6-12.2	4.4-13.3
Ocean-type sockeye[c]	3.7	-	>25	2-20	22	66	12	4.2-9.0	3.5-10.0
Chinook	9.1-10.0	13.4-20.1	>24	30-91	6	72	22	5.6-13.9	5.0-14.4
Coho	2.8	11.7	>18	30-91	5	85	10	4.4-9.4	4.4-13.3
Pink	0.6	0.6	>15	21-101	34[d]	66[d]	-	7.2-12.8	4.4-13.3
Chum	2.3	9.2	>18	46-101	6	81	13	7.2-12.8	4.4-13.3
Steelhead	4.4	-	>24	40-91	-	-	-	3.9-9.4	-
Dolly Varden[e]	1.0	-	>30	40-95	3.5	96.5	0	6.1	0.5-8.3

[a] Bjornn and Reiser 1991.
[b] Burner 1951.
[c] Lorenz and Eiler 1989.
[d] McNeil and Ahnell 1964. Results excluded substrate > 10 cm in diameter.
[e] Blackett 1968.

Appendix 2.—Habitat characteristics by channel type for each study reach (Study 2), Situk River, Alaska, and adjacent watersheds 1987-89. A dash indicates no data; a = debris pool, b = willow edge, and c = channel edge.

Variable	Channel type														
	FP1f			FP1s		FP3f						FP3s			
Site no. NMFS	308	408	328	108	409	101	122	304	310	315	330	113	121	201	117
Site no. USFS	308	408	328	501	409	501	201	304	310	315	330	501	112	201	203
Day of year	161	194	203	212	195	201	223	164	232	223	201	205	222	219	220
Reach area (m²)	706	476	306	2630	1537	231	511	169	329	744	494	504	289	204	337
Reach length (m)	75	69	58	180	106	98	82	60	58	87	78	90	50	48	50
% Pool	46.2	61.9	8.6	53.9	0	63.2	32.3	95.2	42.1	47.5	31.2	42.2	42.0	64.0	43.4
% Riffle	0.0	22.9	0.0	9.7	0	21.2	0.0	4.8	35.3	35.8	0.0	20.8	0.0	0.0	30.8
% Glide	53.8	15.2	91.4	36.4	100	15.6	67.7	0.0	22.6	16.7	68.8	37.0	58.0	36.0	25.9
Average depth (cm)	45.8	35.6	56.5	28.5	59.2	9.2	22.7	21.6	18.9	32.7	48.2	15.8	32.8	25.5	25.3
Maximum depth (cm)	82	85	73	150	87	110	64	54	48	54	100	48	75	110	110
Average width (m)	9.4	6.9	5.3	14.6	14.5	2.4	6.2	2.8	5.7	8.6	6.3	5.6	5.8	4.2	6.7
Water temperature (°C)	11.0	13.0	11.5	12.5	15.0	16.7	10.2	13.6	10.0	8.5	9.8	11.8	7.3	11.4	11.0
Stream gradient (%)	0.8	-	-	0.5	0.7	0.5	1.0	<1.0	<1.0	0.0	0.0	0.4	0.5	0.3	0.5
Discharge (m³/s)	0.46	-	0.72	-	0.58	0.05	-	0.01	0.01	0.13	0.60	0.11	0.12	0.08	-
Substrate (% fine)	45.6	41.8	96.6	0.0	100.0	0.0	0.0	78.1	42.1	13.5	97.1	0.0	20.0	75.0	4.0
LWD															
No. of pieces	2	13	0	1	2	4	22	9	5	6	14	0	0	0	6
Pieces/100 m	0.3	18.8	0.0	0.6	1.9	4.1	26.8	15.0	8.6	6.9	17.9	0.0	0.0	0.0	12.0
Volume (m³)	1.1	8.5	0.0	0.2	1.8	3.1	26.6	47.9	9.0	14.1	31.0	0.0	0.0	0.0	6.6
Volume (m³/100 m²)	0.2	1.8	0.0	<0.1	1.7	1.3	5.2	28.3	2.7	1.9	6.3	0.0	0.0	0.0	2.0

Appendix 2.—Continued.

Variable	Channel type					
	FP4f			FP4s		
Site no. NMFS	301	311	318	103	317	104
Site no. USFS	301	236	189	503	200	504
Day of year	158	236	189	202	200	220
Reach area (m²)	2094	2953	1684	626	923	3593
Reach length (m)	136	132	122	85	108	180
% Pool	63.6	25.4	66.3	25.4	53.7	66.6
% Riffle	20.3	5.5	7.1	31.3	13.0	14.5
% Glide	16.1	69.1	26.6	43.5	33.3	19.0
Average depth (cm)	17.9	41.0	31.0	18.2	40.6	27.5
Maximum depth (cm)	56	65	52	67	62	101
Average width (m)	15.4	22.4	13.5	7.4	8.6	20.0
Water temperature (°C)	16.0	8.5	8.5	12.2	11.7	7.7
Stream gradient (%)	0.0	1.0	-	1.0	-	0.6
Discharge (m³/s)	0.34	1.69	0.29	0.42	0.29	0.34
Substrate (% fine)	0.0	26.6	11.7	0.0	37.4	25.0
LWD						
Number pieces	39	2	13	3	-	7
Pieces/100 m	28.7	1.5	0.0	3.5	-	3.9
Volume (m³)	44.8	0.1	0.6	13.2	-	5.6
Volume (m³/100 m²)	2.1	0.1	0.4	2.1	-	0.2

Appendix 2.—Continued.

Variable	Channel type											
	FP5f											
Site no. NMFS	410	411	412	115	111	322[a]	415[a]	416[a]	415[b]	416[b]	415[c]	416[c]
Site no. USFS	410	411	412	207	507	322	415	416	415	516	415	416
Day of year	214	221	243	203	211	188	220	223	220	223	220	223
Reach area (m^2)	3233	3683	3090	2504	7139	740	213	300	74	80	74	74
Reach length (m)	122	127	100	110	220	75	30	40	21	21	20	20
% Pool	16.5	7.4	5.6	25.9	7.6	100.0	100.0	100.0	0.0	0.0	0.0	16.7
% Riffle	66.5	59.6	77.0	44.2	42.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
% Glide	17.0	33.0	17.4	29.9	50.6	0.0	0.0	0.0	100.0	100.0	100.0	83.3
Average depth (cm)	47.2	35.0	30.8	34.5	30.7	46.0	153.0	121.0	95.0	75.0	26.3	35.7
Maximum depth (cm)	70	58	78	140	140	75	270	260	180	110	46	100
Average width (m)	26.5	29.0	30.9	22.8	32.5	9.8	7.1	7.5	3.5	3.8	3.7	3.7
Water temperature (°C)	-	18.0	-	12.4	12.0	-	-	-	-	-	-	-
Stream gradient (%)	-	-	-	0.5	0.7	-	-	-	-	-	-	-
Discharge (m^3/s)	-	-	-	1.96	5.71	5.41	-	-	-	-	-	-
Substrate (% fine)	7.9	11.4	8.2	-	-	-	-	-	-	-	-	-
LWD												
Number pieces	3	14	8	34	5	107	25	8	0	0	0	1
Pieces/100 m	2.5	11.0	8.0	30.9	2.3	142.7	83.3	20.0	0.0	0.0	0.0	5.0
Volume (m^3)	11.3	29.9	2.0	30.2	2.9	292.8	-	-	0.0	0.0	0.0	-
Volume ($m^3/100\ m^2$)	0.3	0.8	0.01	1.2	<0.1	39.6	-	-	0.0	0.0	0.0	-

Appendix 2.—Continued.

Variable	Channel type								
	FP5s								
Site no. NMFS	319[a]	413[a]	414[a]	309[b]	323[b]	413[b]	414[b]	413[c]	414[c]
Site no. USFS	319	413	414	309	323	413	414	413	414
Day of year	237	219	222	162	223	219	222	219	222
Reach area (m^2)	300	230	195	504	169	88	86	74	74
Reach length (m)	62	45	33	134	55	21	21	20	20
% Pool	100.0	100.0	100.0	100.0	100.0	0.0	0.0	33.3	33.3
% Riffle	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
% Glide	0.0	0.0	0.0	0.0	0.0	100.0	100.0	66.7	66.7
Average depth (cm)	50.5	77.0	108.0	109.4	125.8	62.0	116.0	29.3	27.7
Maximum depth (cm)	80	250	180	201	247	90	150	72	60
Average width (m)	4.8	5.1	5.0	3.7	3.1	4.2	5.9	3.7	3.7
Water temperature (°C)	9.5	-	-	12.8	11.5	-	-	-	-
Stream gradient (%)	-	-	-	1.0	-	-	-	-	-
Discharge (m^3/s)	-	-	-	6.02	-	-	-	-	-
Substrate (% fine)	-	-	-	-	-	-	-	-	-
LWD									
Number pieces	56	14	9	1	0	0	0	0	1
Pieces/100 m	90.3	31.1	27.3	0.7	0.0	0.0	0.0	0.0	5.0
Volume (m^3)	118.5	-	-	0.2	0.0	0.0	0.0	0.0	-
Volume ($m^3/100\ m^2$)	39.5	-	-	0.2	0.0	0.0	0.0	0.0	-

Appendix 2.—Continued.

Variable	Channel type												
	PA1							PA2	PA3				
Site no. NMFS	102	302	305	324	325	327	329	120	106	123	105	303	326
Site no. USFS	502	302	305	324	325	327	329	204	506	210	505	303	326
Day of year	202	159	160	186	235	22	199	221	204	223	208	164	233
Reach area (m^2)	130	71	231	53	168	114	201	2292	268	748	885	1204	798
Reach length (m)	60	38	65	39	40	68	62	133	74	75	115	79	75
% Pool	79.8	100.0	100.0	93.0	8.1	83.1	94.9	21.2	100.0	100.0	98.2	96.3	99.2
% Riffle	6.3	0.0	0.0	0.0	0.0	16.9	5.1	0.0	0.0	0.0	1.8	1.9	0.0
% Glide	13.9	0.0	0.0	7.0	91.9	0.0	0.0	78.8	0.0	0.0	0.0	1.8	0.8
Average depth (cm)	14.2	14.8	21.5	44.7	49.7	39.6	29.5	13.1	11.3	27.7	16.0	33.9	61.8
Maximum depth (cm)	52	25	39	100	74	60	68	38	32	74	44	56	110
Average width (m)	2.2	1.9	3.6	1.3	4.2	1.7	3.2	17.2	3.6	10.1	7.7	15.2	10.6
Water temperature (°C)	11.7	11.5	13.1	12.3	11.0	6.8	12.8	17.0	21.4	12.1	8.0	12.1	9.4
Stream gradient (%)	1.0	<0.5	<0.5	-	-	-	-	-	0.8	<0.5	<0.5	<0.5	-
Discharge (m^3/s)	0.01	<0.01	0.02	0.02	0.33	0.02	0.01	-	-	0.04	<0.01	0.15	0.01
Substrate (% fine)	30.0	85.0	100.0	96.5	71.8	49.5	73.3	6.0	5.0	12.0	80.0	88.8	79.9
LWD													
Number pieces	0	0	9	0	2	0	5	0	0	2	0	0	3
Pieces/100 m	0.0	0.0	3.9	0.0	1.2	0.0	2.5	0.0	0.0	2.7	0.0	0	0.4
Volume (m^3)	0.0	0.0	3.1	0.0	0.5	0.0	0.4	0.0	0.0	0.1	0.0	0.0	2.0
Volume (m^3/100 m^2)	0.0	0.0	1.3	0.0	0.3	0.0	0.2	0.0	0.0	<0.1	0.0	0.0	0.3

Appendix 3.—Population number and density of juvenile salmonids by channel type and study reach, (Study 2) Situk River, Alaska, and adjacent watersheds 1987-89. (a = stream from adjacent watershed; b = smolt; p = fry present but population not estimated.)

Variable	Channel type														
	FP1f			FP1s		FP3f						FP3s			
Site no. NMFS	308[a]	328[a]	408[a]	409[a]	108[a]	101	122[a]	304	310	315	330[a]	113[a]	121[a]	201	117
Site no. USFS	308	328	408	409	501	501	301	304	310	315	330	501	112	201	203
Day of year	161	203	194	195	213	202	224	164	232	223	201	206	223	220	220
Reach area (m^2)	706	306	476	1537	2630	231	511	169	328	744	493	504	289	204	337
Reach length (m)	75	58	69	106	180	98	82	60	58	87	78	90	50	48	50
Population no.															
Coho	727	455	662	1281	3693	705	788	308	373	1879	629	575	324	518	1387
Proportion fry	0.29	0.77	0.80	0.04	0.93	0.96	0.36	0.91	0.94	0.90	0.75	0.88	0.90	0.67	0.85
Fry	211	350	528	56	3420	674	284	279	351	1690	472	503	293	345	1178
Parr	516	105	134	1225	273	31	504	29	22	188	157	72	31	173	209
Sockeye	0	0	0	8	26	0	0	0	0	0	0	0	0	0	8
Fry	0	0	0	0	26	0	0	0	0	0	0	0	0	0	8
Parr	9	0	0	8	0	0	0	0	0	0	0	0	0	0	0
Steelhead	3	11	67	2	0	0	0	0	104	28	0	5	0	25	10
Fry	0	0	0	0	0	0	0	0	88	0	0	0	0	p	p
Parr	3	11	67	2	0	0	0	0	16	28	0	5	0	25	10
Chinook fry	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Dolly Varden	1	0	0	0	1	3	23	3	19	835	14	1	35	0	100
Population density (no./100 m^2)															
Coho	103	149	139	83	140	305	154	182	114	252	126	114	112	254	412
Fry	30	115	111	4	130	292	56	165	106	227	95	100	101	169	350
Parr	73	34	28	80	10	13	99	17	7	25	31	14	11	85	62
Sockeye	1	0	0	1	1	0	0	0	0	0	0	0	0	0	2
Fry	0	0	0	0	1	0	0	0	0	0	0	0	0	0	2
Parr	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Steelhead	0	3	14	<1	0	0	0	0	31	4	0	1	0	12	3
Fry	0	0	0	0	0	0	0	0	27	0	0	0	0	p	p
Parr	0	3	14	0	0	0	0	0	5	4	0	1	0	12	3
Chinook fry	0	0	0	0	0	0	0	0	0	<1	0	0	0	0	0
Dolly Varden	<1	0	0	0	0	1	5	2	5	112	3	<1	12	0	30

Appendix 3.—Continued.

Variable	Channel type					
	FP4f			FP4s		
Site no. NMFS	301	311	318	103	317	104
Site no. USFS	301	311	318	503	317	504
Day of year	158	236	189	203	200	221
Reach area (m^2)	2094	2953	1684	626	923	3593
Reach length (m)	136	132	122	85	108	180
Population no.						
Coho	10189	2811	6379	740	5143	1192
proportion fry	0.97	0.99	0.99	0.79	0.69	0.89
fry	9885	2783	6315	585	3549	1056
parr	304	28	64	155	1594	136
Sockeye	672	188	736	0	1	516
fry	0	188	736	0	1	516
parr	672	0	0	0	0	0
Steelhead	710	572	1	454	610	4
fry	0	562	0	p	0	0
parr	710	10	1	454	610	4
Chinook fry	0	2	0	0	3	0
Dolly Varden	8	909	8329	100	354	15835
Population density (no./100 m^2)						
Coho	487	95	379	118	557	33
fry	472	95	377	93	385	29
parr	15	1	2	25	173	4
Sockeye	32	6	44	0	<1	14
fry	0	6	44	0	<1	14
parr	32[b]	0	0	0	0	0
Steelhead	34	19	<1	73	66	<1
fry	0	19	0	p	0	0
parr	34	<1	0	73	66	<1
Chinook fry	0	<1	0	0	0	0
Dolly Varden	<1	31	495	16	38	441

Appendix 3.—Continued.

Variable	Channel type										
	FP5f						FP5s				
Site no. NMFS	410	111	115	415[c]	416[c]	322[e]	309[d]	319[e]	323[d]	413[c]	414[c]
Site no. USFS	410	507	207	415	416	322	309	319	323	413	414
Day of year	214	212	204	220	223	188	167	237	223	219	222
Reach area (m^2)	3233	7139	2504	361	454	740	504	300	169	392	355
Reach length (m)	122	220	110	71	81	75	134	62	55	106	74
Population no.											
Coho	12514	184	3469	677	695	1989	1465	408	1670	2470	4555
proportion fry	0.97	0.99	0.87	0.97	0.94	0.96	0.85	0.96	0.97	0.97	0.99
fry	12193	181	3004	656	655	1909	1245	393	1620	2393	4510
parr	321	2	465	21	40	89	220	15	50	77	45
Sockeye	1	2	0	0	0	0	30	0	0	0	0
fry	1	2	0	0	0	0	30	0	0	0	0
parr	0	0	0	0	0	0	0	0	0	0	0
Steelhead	285	27	18	30	28	273	59	7	168	476	200
fry	24	p	p	9	2	0	0	0	0	84	122
parr	261	27	18	21	26	273	59	7	168	392	78
Chinook fry	331	0	0	2	25	1177	523	0	122	80	23
Dolly Varden	47	3	3	5	2	15	36	0	7	16	9
Population density (no./100 m^2)											
Coho	387	3	139	188	153	123	291	30	988	631	1284
fry	378	3	120	182	144	118	247	29	959	611	1271
parr	10	<1	19	6	9	5	44	1	30	20	13
Sockeye	<1	<1	0	0	0	0	1	0	0	0	0
fry	<1	<1	0	0	0	0	1	0	0	0	0
parr	0	0	0	0	0	0	0	0	0	0	0
Steelhead	9	<1	1	8	6	17	12	1	99	122	56
fry	1	p	p	3	0	0	0	0	0	21	34
parr	8	<1	1	6	6	17	12	1	99	100	22
Chinook fry	10	0	0	1	6	73	104	0	72	20	6
Dolly Varden	1	<1	<1	1	<1	<1	7	0	4	4	3

Appendix 3.—Continued.

Variable	Channel type												
	PA1							PA2	PA3				
Site no. NMFS	102	302	305[a]	324	325	327	329[a]	120	106	123	105	303	326
Site no. USFS	502	302	305	324	325	327	329	204	506	210	505	303	326
Day of year	203	159	160	186	235	221	199	222	205	224	209	164	233
Reach area (m^2)	130	71	231	53	168	114	201	2292	268	745	885	1204	798
Reach length (m)	60	38	65	39	40	68	62	113	74	75	115	79	75
Population no.	233												
Coho	140	501	27	246	608	21	546	4061	2159	639	231	11893	895
proportion fry	0.56	1.0	0	0.52	0.84	1.0	0.93	0.88	0.83	0.77	0.88	0.99	0.90
fry	78	501	0	128	511	21	508	3582	1785	493	203	11721	806
parr	62	0	27	118	97	0	38	479	373	146	28	172	89
Sockeye	2	0	1	4	0	0	0	16	267	161	0	31	64
fry	2	0	1	4	0	0	0	16	267	161	0	31	64
parr	0	0	0	0	0	0	0	0	0	0	0	71	0
Steelhead	6	0	0	7	39	0	13	0	0	0	0	0	0
fry	0	0	0	0	29	0	0	0	0	0	0	0	0
parr	6	0	0	7	10	0	13	0	0	0	0	0	0
Chinook fry	0	0	0	0	4	0	0	0	0	0	0	0	0
Dolly Varden	20	0	0	41	150	6	6	0	52	4	370	59	24
Population density	20	0	0	172	89								
(no./100 m^2)													
Coho	108	703	12	469	362	18	272	177	806	86	26	987	112
fry	60	703	0	244	304	18	253	156	667	66	23	973	101
parr	47	0	12	226	58	0	19	21	139	20	3	14	11
Sockeye	2	0	0	10	0	0	0	1	100	22	0	7	8
fry	2	0	0	10	0	0	0	1	100	22	0	1	8
parr	0	0	0	0	0	0	0	0	0	0	0	6	0
Steelhead	5	0	0	14	35	1	8	0	0	0	0	0	0
fry	0	0	0	0	30	0	0	0	0	0	0	0	0
parr	5	0	0	14	6	1	8	0	0	0	0	0	0
Chinook fry	0	0	0	0	3	0	0	0	0	0	0	0	0
Dolly Varden	15	0	0	79	89	5	3	0	19	1	42	5	3

GLOSSARY

The following definitions pertain to terms and acronyms as used specifically in this report.

ADF&G: Alaska Department of Fish and Game.

Channel type: Stream segments that have fairly consistent physical characteristics. A stream classification system developed by the U.S. Forest Service and based on channel types was used in Study 2.

Estuary basin: The deepwater portion of the Situk estuary that is permanently flooded.

Fork Length (FL): Fish length measured from tip of snout to fork of tail.

Fry: A juvenile salmonid that has reared less than a year in fresh water (age 0).

Juvenile: A salmonid fry, parr, presmolt, or smolt prior to entering seawater.

Lake type: Sockeye that rear in lakes during their juvenile freshwater life stage.

Lower river: The approximate 3.5 km lowermost section of the main-stem Situk River influenced by daily tides.

LWD: Large woody debris; a term used to describe logs, tree boles, rootwads, and limbs that are in or near the stream channel. Woody material >10 cm in diameter and ≥3 m long.

MOU: Memorandum of understanding; an official written agreement between agencies.

MS-222: Tricaine methanesulfonate; a fish anesthetic and tranquilizer.

NMFS: National Marine Fisheries Service.

Ocean type: Sockeye and chinook salmon that migrate to sea their first year (age 0).

Parr: A juvenile salmonid that has reared one or more years in fresh water; has distinct parr marks and no silver body coloring.

Predicted flood zone: The portions of the Situk River, Lost River, and Kunayosh Creek watersheds that will be inundated from the overflow of glacial water from Russell Lake after the Hubbard Glacier dams Russell Fiord.

Presmolt: A juvenile salmonid with physical characteristics intermediate between a parr and a smolt (faint parr marks and silvery sheen to scales).

Restoration: The means of returning the carrying capacity of salmonid habitat to a previously existing level.

Restoration strategies: Possible approaches to consider when restoring habitat and anadromous fish after flooding, based on research and other available information presented in this report.

Riverine: River habitat.

Rotary-screw trap: A floating trap with a revolving cone used to catch juvenile downstream migrant salmonids (see Fig. 7.2).

Smolt: Juvenile salmonids that are physiologically capable of adapting to seawater; have distinct morphological characteristics (e.g. silvered body, darkened fin tips).

Stock: Group of fish that is genetically self-sustaining and isolated geographically or temporally during reproduction.

Tidal slough: Quiet-water estuarine habitat in tidal wetlands, containing brackish water and typically bordered by *Carex* sp.

Upper river: The section of the main-stem Situk River upstream of tidal influence.

USFS: United States Forest Service.